A SYSTEM

OF

GEOLOGY,

WITH

A THEORY OF THE EARTH,

AND AN EXPLANATION OF ITS CONNEXION

WITH THE SACRED RECORDS.

BY

JOHN MACCULLOCH, M. D., F. R. S., &c.

IN TWO VOLUMES.

VOL. II.

LONDON:

LONGMAN, REES, ORME, BROWN, AND GREEN,

PATERNOSTER ROW.

1831.

LONDON:
Printed by J. Teuten, 14, Dean Street, Soho.

CONTENTS.

Chap.		Page.
XXII.	*On changes in the disposition of the Sea and Land*	1
	PART II.	
XXIII.	*Classification of Rocks*	65
XXIV.	*Granite*	81
XXV.	*Overlying and Trap Rocks*	102
XXVI.	*Gneiss. Compact Felspar*	141
XXVII.	*Micaceous Schist. Chlorite Schist. Talcose Schist*	157
XXVIII.	*Hornblende Schist. Actinolite Schist*	170
XXIX.	*Quartz Rock. Red primary Sandstone*	174
XXX.	*Argillaceous Schist*	184
XXXI.	*Diallage Rock*	193
XXXII.	*Serpentine*	197
XXXIII.	*Limestone.—Primary*	207
XXXIV.	*Lowest, or old red, Sandstone*	213
XXXV.	*Upper Sandstones*	225
XXXVI.	*Secondary Limestones*	235
XXXVII.	*Shale, Clay, Sand, Marl*	248
XXXVIII.	*General Remarks on the Secondary Strata*	255
XXXIX.	*Pitchstone*	266
XL.	*Jasper, Siliceous Schist, Chert*	273
XLI.	*Gypsum, Rock Salt*	288
XLII.	*Coal*	295

Chap.		Page.
XLIII.	*Lignites*	314
XLIV.	*On Peat*	335
XLV.	*On the Alluvial Deposits*	360
XLVI.	*On Theories of the Earth*	380
XLVII.	*Sketch towards a Theory of the Earth*	410

APPENDIX.

I.	*On the Instruments requisite to a Geologist*	462
II.	*On the construction of Geological Maps*	468
III.	*On conducting and describing geological observations*	469
IV.	*On the qualifications required by a Geologist*	477

ERRATA.

Page 5 — *last line for* hrase *read* phrase
56 — *l.* 20 *after* beyond *insert* the
140 — *l.* 6 *&* 7 *interchange* western and eastern
153 — *l.* 1 *for* assume these *read* assumes the
185 — *last line but one for* uniting *read* unity.
284 — *l.* 7 *for* form *read* term
314 — *last line for* lignite *read* lignites
319 — *l.* 5 *for* descibed *read* described
346 — *last line for* latter *read* former
360 — *dele* the *before* unknown
371 — *l.* 5 *for* these *read* there
384 — *last line for* premised *read* promised
425 — *l.* 16 *for* it did *read* did it
435 — *l.* 25 *after* philosophers *insert a comma.*
478 — *l.* 23 *for* superflous, *read* superfluous,

GEOLOGY.

CHAP. XXII.

On changes in the disposition of the Sea and Land.

Having thus brought down the history of the Globe to the period at which we must believe that it had undergone its last important changes, and was, fundamentally at least, what we know it now, it remains to pursue those which it has since experienced, and is still undergoing; exclusively however of the production of coral and the agency of volcanoes, already discussed. I have shown the difficulty of ascertaining the exact nature of the last great marine emergence of the land, especially as it relates to Time; as also that a long period must have been occupied in minor and posterior revolutions; but although proving, therefore, that the received notion of one brief and complete Emergence, determining the present face of the sea and land, is incorrect and careless, this subject must be treated from such an imaginary condition: that I may avoid a complication as intolerable, as it must be, in its details, conjectural.

Under such a view, the dry land must have been a desert of rocks, without other soil than such alluvium as might have been brought up from the bottom of the sea; without plants, and without animals; the formless and void earth which anteceded the recorded Creation. In what manner to modify this simple and abstract view, by any conjectures worth making, is not now within the power of Geological information. But under any views of later and partial changes, a consider-

able period must have elapsed before this earth, thus empty, was fitted for the reception of at least, terrestrial life. Soil must have been prepared for vegetables; and that soil was the produce of time; though, in addition to the submarine alluvia of the previous ocean, many portions of the land must have retained the alluvium and soil of a former period, since I have shown that there could have been no revolution in which some dry land did not remain. At what periods animals and vegetables were placed in this renovated earth, physical evidence does not enable us to discover: and it must be remembered that, on this subject, the enquiries of Geology are properly and purely physical. If deductions are to be formed from them in support of the Historical records, they can have no value but by maintaining the physical enquiry pure. To fabricate systems out of historical records, and then to use them in support of those very records, is a species of logic which seems to have taken refuge in geology when abandoned everywhere else.

While the land of the original earth was higher than the present, the ocean was deeper. Time has shallowed, and is still shallowing, these seas, and levelling these mountains; it is changing the outlines of our continents; and in rendering the rocky surface more extensively habitable, it is also enlarging it, as it will continue to do while the earth shall endure. He who shall divest the present surface of all but its rocks, who shall exterminate from our maps the great alluvial plains and deltas of the globe, with the countless interior tracts of the same nature, will produce a sketch of the original earth, in no small degree interesting. It is through decomposition and disintegration, aided by mechanical power, that these changes have been produced. Whatever other causes have aided, the waste of the rocks, and the transference of their materials,

are hourly and obvious. In the mountains, they are seen in every fragment; and every river carries with it something to be deposited in the beds of lakes, in the lower lands, or in the seas: while the movements of the ocean transfer the materials which its shores received; spreading them to form the germs of future strata. But the velocity of this process is variable. The nature of the climate, the forms of the land, the qualities of the rocks, with numerous minuter causes, everywhere modify results which still terminate in that destruction to which every thing must submit. In Egypt, the resistance of the works of nature is not less remarkable than that which still preserves its architecture for our instruction; and while the waste of the lower lands of England is imperceptible, every winter is taking from the mountains of Scotland to add to its plains and shores. And thus also does the more durable granite long brave those elements under which the softer sandstones are hourly yielding. The alluvia themselves will be examined in a future chapter; the business of the present is of a more general and comprehensive nature.

Of Rivers and their actions.

The actions of rivers consist in destruction and in reproduction; the former process being evidently subservient to the latter, and the whole constituting one of the great Designs of Nature, for ends of the highest importance respecting both a nearer and a more distant future. I commence, of course, with the process of destruction.

From the moment that the rains first descended, the rivers began to flow: but if there was, at the beginning, such a condition of the atmosphere as has reasonably been supposed, from the preceding effect of heat on the ocean, the fall of water, and the consequent flow

along the surface, must have been far greater than any system of rivers now indicates. That question must be reserved, though we must seek the explanation of many appearances in this state of things; not, as they have been commonly sought, in those actions of rivers which we now witness and to which I must at present limit myself. The waters, thus draining along the declivities, hastened to the lowest levels, by the channels which the irregular elevations of the rocky surface must have produced; uniting into main trunks, and leaving lakes in their courses, as they do at this day. It is true, that the rivers of our own days are not those of antient times; yet whatever may be their actual direction, their general course was determined by the positions, altitudes and inclinations of the elevated strata. If the present chains of mountains have been lowered, and their forms rendered more complicated by the enlargement and multiplication of their vallies, they still occupy the same places; while, with the nature of the rocks and the inclinations of the strata for our guides, we can safely infer that the general division of the waters over a given country is the same now as it was from the beginning. Near their sources however, they probably still correspond exactly; the present ravine being an enlargement of the original fissure, as the mountain valley occupies the depression which first tempted the waters to seek the present passage. If, even in these higher elevations, the courses have sometimes been changed, in consequence of the waste of the rocks, the general conclusion remains. It is in the lower grounds that the great changes have occurred; since it is in these that they have either essentially modified, or even made their channels; ever changing them also, and unavoidably so, when they deposit the very land through which they must construct a passage.

Thus, partly modified and partly made, the present

channels of rivers consist of numerous branches, uniting at many successive levels into a main trunk, so as to form a perfect system of drainage. In the mountain, the river is a torrent; if a precipice occurs, it is a cataract; if a valley intervenes, more depressed near the mountain than at its further extremity, its waters spread into a lake; while, finally, it wanders slowly along the level plain till it reaches the sea. But nothing of all this is permanent. The cascade is deserted or destroyed; the torrent becomes the clear and rapid stream of the elevated valley, the lake is either filled, or is drained by the lowering of its exit, and is converted into a plain, while the stream becomes continuous; and the river of the plain for ever changes its place as it protrudes fresh materials to retard its termination in the sea.

Under the distance of time at which the original actions of rivers commenced, it might be supposed that we could no longer trace the first condition of things. But the process is ever new, and ever recommencing from the same point. If ended in one place it is beginning in another; and thus, in examining a river from its sources onwards, we trace that which the channel was when the river first began to flow, as we follow the whole series, to the present hour and to all future days. The sinuosity or the fissure of the mountain rock is the picture of the original surface, which, giving passage to the waters, at length becomes a ravine: its sides gradually crumbling, and, by their friction on the bottom, aiding the water to deepen its bed. Hence, among stratified rocks, that correspondence of the strata on the opposite sides, which equally occurs in wider vallies, since this is the further progress and enlargement of the ravine. Hence have such ravines been idly attributed to earthquakes, or, as is the vulgar hrase, to "convulsions of Nature:" causes as unne-

cessary, in this case, as in many others where they are equally misapplied by those who are alarmed to find them applied to the very different phenomena which they have really caused. That such actions have produced analogous effects, there is little reason to doubt; but while it is difficult to point out the cases, we are sure that the flow of water, sudden and powerful, or slow and gradual, is capable of fulfilling all the conditions: though it must not be forgotten that the fractures consequent on the elevation of the strata must have also produced every species of discontinuity, from the simple fissure to the wider valley. Still, if there be any cases which especially mark the action of water, it is precisely those where this correspondence of strata occurs; since any more violent and sudden cause must have disturbed this regularity. Yet the want of such correspondence does not prove the reverse: since such a displacement as should destroy the continuity of a set of strata, is precisely that which would give access to water with all its consequent effects.

The cataract is generally connected with the ravine, and the actions are so exactly those which must have commenced from the very beginning, that it demands the next consideration. The most obvious effect is the retrogradation of the cascade in certain cases, with its destruction in others; as, in peculiar positions, it is the production of a deep fissure, at length to become a ravine, and ultimately a valley. In Scotland, the fact of simple retrogradation is seen at the Cauldron linn, and on the Braan at Dunkeld, where the lateral deviation is not less remarkable than the depression of the river. If the marks in these places are trifling, they are instructive: but at Foyers, the excavation is as striking from its depth and magnitude, as from its picturesque beauty; as Kea cloch affords examples of every effect that running water can produce. And a

better eye than that which determined the vale of the Tay above Birnam to have been once a lake, will discover its antient cataracts in the rock, now a hundred feet above the river, and far removed in lateral position from its present bed. Let those who are so free in the use of deluges, thus learn a lesson of caution in pronouncing on what demands a very different eye than that for a stratum or a specimen, and a species of knowledge which geologists have too much forgotten to acquire. Niagara itself is retreating daily; and when this act of geological suicide shall be completed, some posterity will trace the silent seat of that which was the wonder of our own days.

The drainage of lakes may be placed at this stage of a river's action; occurring, as it does, by the lowering of the original rocky boundary through the corrosive powers of the issuing stream; while I need not dwell on the separate case where the same consequence results from the removal of alluvia, formerly laid down, and producing the barrier. If the lake is obliterated through the accumulation of alluvia, the result will be a plain: in the present case, it must be a valley of some kind, yet not without an alluvial bottom. If the common opinion respecting Thessaly be true, it is a striking case in point, the Peneus being the cause; and in this manner will the great chain of the American lakes be assuredly drained at some distant day, by the operations of Niagara. If, essentially, Glen Roy was drained in this manner, yet it must have been by sudden and repeated actions, as is proved by its peculiar phenomena, which I have elsewhere described and analysed. That Loch Maree will, partially at least, undergo the same fate, at some future time, is certain: and if I here remind the reader of the Lake of Constance, it is for the purpose of recalling his attention

to one of the sources of the so long mysterious fresh water deposits.

But the great visible effect of rivers consists in the excavation of valleys; correlatively also modifying the original forms of the mountains. The ravine continues to enlarge by the further destruction of its sides; at length becoming a narrow valley, and successively a wider one, finally uniting at times to a plain or the sea, in an almost imperceptible manner; and thus a system of successive valleys becomes shaped, if not formed, in the course of a river and its tributary streams; replacing what was originally a system of rocky ravines, or of valleys not always materially differing, often also containing lakes. Yet in this progress, other causes aid the mere action of the stream; the decreasing declivities of the hills being corroded by the rains or other causes of disintegration, while graivty aids the descent of alluvia, to be carried off by the water, with all the rest, and to produce other work for the still flowing river to perform. If "diluvian" or general currents have been supposed to aid in these excavations, I cannot perceive that any proof of this has yet been produced, except in the single and rare case of the bursting out of a lake; a source of destruction which I must hereafter notice, while some instances were quoted in an early chapter.

If it remains to trace the further process of destruction by a river, I must now consider it as having ceased to act on the solid rock, since, henceforward, it flows through the alluvia which it has transported from the higher grounds. There is, thus, a process of production, anticipating that of destruction: but these two branches of the subject become here inseparable.

The destructive operation in this case being that of removing alluvia, these have been often supposed of

"diluvian" origin, especially by those who seek physical information where it was never intended, and is assuredly not to be found. This is to be ignorant of the action of a river, in which the two distinct processes of laying down and of removing materials are always going on; while the two effects, which appear to be coexistent in one place, occur, at one point of time, in two places, and are in a state of perpetual transference. The torrent, gradually deepening its rocky bed, carries forward its materials to a lower point, thus diminishing the rapidity of the slope on which it flowed: while, continuing to act on these, it labours to restore the declivity which it had reduced, thus deepening its channel and transferring them to a lower point. Hence the raising of the bed by the protrusion of materials, and the lowering of it by vertical wear, proceed at the same time: the former, however, preceding the latter, or the work of elevation going on at a point nearer the source, at any instant, than that of deepening. Though the final result would be to equalize the mountain and the sea, the powers gradually diminish, or the time encreases, with the diminution of the declivity, and is thus always most feeble in the plains. But here also it lays down what it will remove, and removes what it has laid down: while the results are modified by lateral deviations arising from the evanescence of the declivity and from obstructions of its own creating; through the fall of its banks or other causes. Hence arises the depth of deserted alluvia in the wider valleys and the plains, with their permanent elevations above the actual course of the river which created them. And these are the alluvia which some have viewed as "diluvian," as others have supposed them to belong to deserted lakes; unaware of the nature of what I have thus, if too briefly, analysed. The very valley, thus giving an allu-

vial course to a stream, once carried that over its rocky bottom; as that bottom, successively lowered, can often be traced on the declivities of the hills, displaying those marks of wear which have so often been idly attributed to diluvian currents.

Such is all the analysis I can here afford of this particular branch of a subject which might well occupy a volume; but I must here notice one or two of the main consequences of this destructive power. Such are the changes of place to which rivers are subject; too often neglected or misapprehended. Among these, the change of the course of the St. Lawrence near Quebec is one of the most noted. In this way also, the Soane, which once joined the Ganges at Patna, is now many miles distant from it at that place; while the Cosa once met it almost fifty miles lower than it does now. Thus too did Lahore lose its commerce by the alterations of the Ravee. If the Burhampooter is noted for the changes of its channel, the same is true of the Wolga and of many other rivers: while, in our own country, under other changes, the Almond, once entering the sea above Perth, now flows into the Tay, while the Earn joins it at that almost neutral point which shows, at once, what it was and what it is destined to be. Of mere changes of level and place within the same valley, the examples are endless. If Saussure has noted the course of the Rhine on the side of Mont Salève, I have already pointed out a similar case in the Tay, while such examples can be traced everywhere. In plains, these changes are far more complicated and extensive; while the reason must now be obvious, in the nature of the materials of the bed, and of the declivities: and thus a great river in a great plain wanders over miles in the course of centuries, while thus also does it either multiply its channels or the reverse. All geography furnishes endless exam-

ples of this; but none better than the plain of the Ganges, respecting which all may read what I have no room to quote.

I must here also notice one consequence occurring in the lower portion of a river, where art has interfered; from its great economical importance. The tendency of the stream is to wander, and it is the object of embankments to restrain that, as to check inundation. Hence the materials with which the water would have elevated the plain, in the performance of its appointed duty, become deposited in the channel; thus raising its bed, and therefore rendering necessary a higher embankment, and also a prolongation of that towards its source. Thus is the river forced up above the plain, and thus does the plain itself become a depressed meadow, often difficult of drainage, and often a marsh: while the gradual extension of these upwards, with a comparative depression of their level, produces and extends those lands which are the notorious sources of disease. Such is the well-known state of the Mississipi at New Orleans, and such is that of the Po; now running, in some parts, almost on the summit of a dyke, so as to have led to serious reflections on the necessity of allowing it to break loose and find a new bed. And that this also is the state of the Thames, I need not say; while the pressing result at present, is the increasing depression of Westminster beneath the full stream.

The last remark respecting the shifting of rivers is important, on account of some false conclusions, of the usual nature, drawn from the traces which they have left where they no longer flow, or from great accumulations of alluvia in the course of a mere rill. Respecting the former, I need add no more: he who will exert himself will often find the real causes of what he desires to think a "diluvium," and probably a relic of

the Mosaic deluge. The other case is more abstruse, and of peculiarly difficult investigation. In either, the source of the alluvia cannot be mistaken; from that regularity of stratification which can only occur in the case of a river deposit, the facts being such as not to admit of a former lake; and if the original stream cannot be found in the neighbourhood, the only remaining solution is, that of the lowering of the mountains, through the usual waste; thus cutting off that supply of water which originally produced a large river where there is now but a rill, or perhaps nothing. Of such extensive losses of land there can be no doubt, as I shall show hereafter; while it is obvious that higher lands must have produced larger rivers. And when I find that the most striking cases of this nature occur at the foot of trap ridges, so especially bearing marks of great waste, this solution becomes even more satisfactory.

In concluding this branch of the action of rivers, it is now evident that I but partially agree with those who, in their eagerness after a system, have asserted that all valleys have been excavated by their rivers: while it must be plain that the long-continued dispute among geologists, whether the beds of rivers had been prepared, or were made by themselves, is but the dispute of children in this science. It is evident that the original drainage consisted in the irregularities of the elevated rocky surface; nor can I understand how this necessity should have been overlooked by those with whom this forms an essential part of the whole system. Were the rivers the causes of the valleys, every land should have been a table of mountain, without other discontinuity than a fissure. Were this theory true, how is there any lake at all; above all, how are there such lakes as Loch Ness, many hundred feet deeper than the surrounding seas? No river could have ex-

cavated these: and the lake is but a valley, though such reasoners forget it: while if the early surface contained valleys of such a form, it might as well have contained all others. The original courses, if not the channels, of the rivers were made for them, but they have modified those: as they have necessarily been the fabricators of their own beds where these exist in alluvial and protruded lands. All this is as obvious as it is simple. But all geology is, throughout, like all the works of nature, too simple for those who cannot see what is, who seek in their own inventions for what is not, and who also delight in mysteries. It has been the history of all the sciences: and all flounder alike, till a Newton arises, to see and demonstrate the truth.

I ought not to be compelled to pursue this subject through such asserted cases as the Lake of Geneva: but authority sanctions every absurdity—while it holds, as it is the steady enemy to improvement and truth. If we compare that lake with the Valais, it is impossible to believe that it could have received all the materials of that valley, and still retain the depth which it possesses; increase the original extent of the cavity as we may: while, since there was such a vacuity, such a valley, here, from the beginning, why was there not one also in the Valais, and why should that, peculiarly, have been excavated by its river? What power of rivers excavated the great Caledonian valley, even though it had not contained Loch Ness: and where are the rivers which produced all the Western Highland inlets? for these are valleys also. Like thousands more, they are the original valleys of the surface: rivers may have modified their forms; but they were not made by any river.

If I have thus terminated this part of the subject, I can afford but little further illustration; while gladly pointing out, at home, where all can see, what those

who prefer illustrations of higher and foreign name may read of; commonly with little useful understanding of the subjects, and, too often giving their faith to doubtful recorders and to makers of hypotheses. Any map of the great rivers of the world will show the extent and places of that system of connected and successive levels which conducts water from its several sources to the sea. There are such systems, whose perfection is owing to the action of the rivers which they now conduct in so smooth a manner: there are others which, interrupted by lakes and cataracts, indicate what nature did at first, and what the river has yet to do. These last are the instructive ones; and, in our own island, the Tay is an epitome of every thing: but he who desires to understand, must examine what I can but indicate in a small portion of its multifarious branches. The Dochart is fast filling its lake, and will in no long time hold its uninterrupted course through that valley: long yet however to fall into Loch Tay, through that succession of cataracts at Killin, which, did they retreat faster than the lake fills, would produce an example of the drainage of lakes. Contrasted with this, the Lochy has finished the working out of its bed, and now enters the lake, at the same place, a sluggish stream. That lake is the first great interruption in the Tay; and centuries must yet pass before it will here have formed its own bed. In the small streams that join the Lyon, we find every mode of the vertical torrent and fissure; and the ravine of the Keltnie demonstrates the depth to which water can act on the solid rocks. The cascades of Moness show what the original courses of all mountain waters must have been, as the great cataract of the Tumel will explain the proceedings of Niagara: while they who will pursue this branch to its source in Rannoch, will see

how little it has yet done in forming its own channel; henceforth, with little exception, to flow in that bed which rivers may truly be said to have formed for themselves. The Forth presents a far longer course of that repose which it has produced for itself; though the well-known lakes among its sources mark the beds which nature prepared for it, and which it has scarcely yet impressed with the marks of change. And if we desire to know the destruction which rivers produce near their entrances into the sea, we can see that the Tamar, the Fowey, and others, once joined it as rapid torrents, if not as cataracts. A cataract in Sky now plunges, a detached stream, over three hundred feet of a perpendicular cliff; while, if the time will come when it must enter a gentle stream, that change is already commenced in a neighbouring one, which meets the sea, a foaming torrent.

Proceeding now to trace the great process of Production, I have already shown that rivers carry to the plains, and finally to the sea, the materials which they have taken from the mountains. But that which they take from one part of the earth to add to another, is disposed of in different ways. At the upper levels, these materials fill the higher valleys or modify their forms; on the lowest, they generate plains; and, at the entrance of the rivers into the sea, they produce banks and islands. In the courses of the streams, they fill up lakes, becoming again known to us; but, once deposited beneath the sea, if they do not cause its bottom to rise above the surface, they are thenceforward known only by the soundings of mariners. Occasional events, however, accelerate and modify these results. The torrent of an hour sometimes performs the work of years: and inundations suddenly raise the plains, or deposit banks and islands at the æstuaries of the streams: as thus also the feeble barrier

of a lake may be at once lowered, though the general cause is far more tedious. It is by its occasional inundation that the Nile raises the valley of Egypt, while its daily actions are merely extending the Delta. Such too is the action of the similarly situated river of Ava, and others of Eastern Asia, and thus do the Wolga, the Yellow river, and others, raise the surrounding plains by their enormous and durable inundations. It must however be recollected, that all alluvia are not the produce of rivers, as has rashly been asserted; and that we may often form erroneous judgments respecting the effects of these, by attributing to them what has been produced by other causes. But this question must be reserved to a future period; at present, it is sufficient that I have stated the possible exceptions. Nor let any one imagine that if all these results demand Time, any thing is here implied, respecting a parallel antiquity in terrestrial beings. The present view refers only to the state of a vacant earth, preparing for the habitation of animals, and is a period respecting which we may freely enquire.

The quantity of the alluvia, in various places, leads us to conjecture of the times during which these actions must have existed, and thus, of the far distant period when first the rivers descended from the naked mountains and the sea rolled every where against a rocky shore. At Amsterdam, 230 feet in depth of alluvial soil have been penetrated, consisting of alternations of sand, clay, gravel, earth, peat, and sea shells. In our own island, the flat æstuaries of the Thames, the Tay, the Forth, and many more, have been filled to their present state by the produce of the hills. But these are trifling examples; a single case of some magnitude is preferable to thousands such which might be quoted, could I give a volume where I am limited to a brief chapter. From the Puranas, we learn that long before

the Christian æra, the Delta of the Ganges extended but a little way below Fulta. Where that river enters the plain at Haradwar, the elevation, by Captain Hodgson's measurement, is 1024 feet; and thus we may compute the declivity of the whole. As the rocks and hills about Birbhoom and to the south-east of Chunar, rise suddenly from a dead level, as if out of the water, it is evident that, even there, the plain has been formed from the deposits of the river; as is further proved by the fact that, through this whole extent it consists of fine sand and clay, or mud; and though the total depth of the deposit has not been reached, it has been penetrated, at Benares, to 105 feet; presenting repeated strata of river sand and clay, alternating with vegetable mould; while, even the antient beds of the river were traced at ninety-five feet in depth, with the bones of men and animals deposited on it. Hence, following the whole of this enormous plain, we may compute, though in a very limited and imperfect manner, the immense quantity of materials which the river must have brought down from the Himálya ridge; while the organic remains also allow us to form a conjecture respecting the period in which this accumulation has taken place. Were it necessary, the United States of America would afford similar inferences; beds of sea shells, and other indications of the former presence of the sea, even at the feet of the mountains, giving proof of the production of all the flatter tracts from the waste of the interior lands.

Such visible accumulations of alluvial soil, added to those which are hidden beneath the sea, may afford some conception of the waste which the rocks have suffered, as of the changes which the face of the land must have undergone, not less from waste than addition: nor, could we revive a few thousand years hence,

should we easily recognise one feature of the countries most familiar to us.

Of the filling of lakes, the whole world presents examples, and we see the process going on every day. Being a subject which concerns physical geography, we may procure abundant information on it, in the works of antient and modern geographers. The boundaries of the Caspian are every day contracting, and the neighbouring deposits of shells and mud indicate its former probable communication with the Aral. The Baikal is diminishing rapidly: and the valley of Cashmire still contains some small lakes, the remains of that which once filled the whole of this basin: as is equally supposed of the valley of Nepaul. In Mexico, in 1520, Cortez found two lakes, the one salt and the other fresh: there are now five smaller ones, produced by the accession of new land; and the whole valley, containing two hundred and forty-four square leagues, of which but one tenth is now water, was formerly a single lake. Here, I need scarcely repeat, we trace the origin of those lacustral "formations," concerning which geologists have made such confusion; as, in the cases just quoted, we equally find those alluvia of the ocean which have so often been confounded with them under the term "Tertiary." If I unwillingly take room for further examples, since thus are books too easily written, teaching nothing, as is the usage, the same is true of the lake of Geneva, diminishing daily; of those of Thun and Brientz, now separated by an alluvial plain; of the valley of the Aar, once a receptacle of water; of Loch Tumel, in our own country, now reduced to less than half its original size; of Loch Rannoch, once flowing at the foot of Mount Alexander; of Crummock and Buttermere, now separated like the Swiss lakes just mentioned; and of Loch Lomond, where

the commencement of this process is seen at the influx of every stream. Thus also is the habitable surface of the earth encreased, in these cases, as it is on the sea shores; and that which was the dwelling of fishes becomes a place for man.

In the higher valleys of hilly countries, the steep sides of the hills become thus fitted for the plough; while the lodgment of alluvia in their lower parts raises the surface, and produces a fertile plain where there was once a barren declivity. Thus also, in the lower plains, the levels are enlarged; while additional fertility is conferred by the finer materials which the waters bring down. Thus has been produced the fertile district of Egypt. Divest it of the mud which interior Africa has supplied, and nothing remains but a steep rocky valley, rolling the Nile along, and admitting the sea within its entrance. Hence the fertile plains of Lombardy, and the extensive tracts which attend the Plata, the Oroonoko, the Amazon, and the Hudson. Mountains useless to man, nearly useless to animals, covered with a scanty vegetation, thus become the seats of nations, regions of fertility, and wealth, and power.

The connexion between the lowest plains and the æstuaries in which they terminate, is so intimate, that the one is but a part of the other: the limit is a "punctum fluens," where that which is now sea is shortly destined to become land. In these cases, the submarine alluvia, first appearing under the form of banks, and lastly under that of islands, extend the solid plain. Whether in lakes or in the sea, the general process is the same. The Wolga enters the Caspian by seventy mouths, the produce of islands afterwards united, and of which fresh ones are forming every day. Thus the Sunderbunds first appear as islands, which, uniting, determine a new aperture for the Ganges, or

change the position of a former one. The bank generated at the mouths of the Nile, by the opposing actions of the stream and of the sea, soon produces an island; which, united to the shore, and becoming the gradual basis of vegetation, extends the region of the Delta. The Gulf of Pe-tche-lee is similarly filled with islands; the extensive shoaling of the shores round the mouths of the Amazon, is the prelude to that further extension which the coast is here undergoing: while the land advances fifteen leagues in a century under the power of the Mississipi. The Gulf of Mexico is gradually filling up in the same manner; though the gulf stream here assists, by means of the earth conveyed along the eastern shore: the land having been so far extended, that shells are now found thirty miles in the interior. If the insignificance of our own rivers does not permit us equally to witness these effects, they are still sufficiently sensible every where, and most distinctly so at the mouth of the Tay.

With respect to the sea line, if the general effect is to change its form by extending the land, the ultimate practical results are very different. Thus towns, once maritime, are now many miles inland; as Ravenna, a sea port in the time of Augustus, is at present, a league from the sea. And thus, as commerce has been excluded from harbours, and wealthy territories ruined, might physical causes have done for Venice, what moral ones have effected with far greater speed. But if this increase, combined with political and moral ruin, has destroyed many more of the once wealthy ports of the Mediterranean, the same operation, in other places, aided by the rise of empire and by industry, has added to the world, cities and harbours not less populous and flourishing; destined in their turns to submit to the same fate, as nature, ever steady, shall triumph over

the diminishing resistance of man. As Alexandria and Carthage have been replaced by Amsterdam and Petersburgh, so will these give away to new cities in other lands, when the term of their prosperity shall be completed. From the same causes islands become peninsulas; and, of this, Gibraltar is a conspicuous instance: as are in our own country, the Mull of Cantyre, and the Garroch head of Bute, with the promontories of Hillswick and Sumburgh head in Shetland. Such changes are in themselves subject to change: from variations in the level or currents of the sea, arising from analogous or other causes; and thus have such tracts been found to vacillate from the one to the other character.

Of the variations in the outline of the sea, few are more important than those by which bays and deep inlets are filled, and converted into land. This occurs, independently of the deposits of great rivers, by a concurrence of the movements of the tides with the forms and directions of shores: the moveable alluvia of the sea being deposited to the lee of the currents, where, aided occasionally by the ruins of the land, and by submarine vegetation, they form banks which first shoal and destroy the harbours, and lastly convert them into plains. In many of the deep inlets of the Highlands, as in Loch Tarbet, this process is very sensible: as, in the other case, the bays on each side of the Chesil bank are gradually diminishing in depth; the finer materials subsiding, to the eastward, under shelter of that ridge, while to the windward, the same bank, checking the direct motion of the gravel, accumulates what the western swell rolls on. But the different modes in which these effects are produced, vary in almost every place; and among them, few are more remarkable than those which occur in the islands of the Indian ocean; where the growth of ma-

ritime forests, extends the well-known marshy tracts by which so many of these shores are skirted; often covering, as in Borneo, spaces almost incredible, and with effects but too well known.

The last geographical effect of this nature which I need notice, is the formation of fresh water lakes on the margin of the sea; being an occasional result of that process which fills a bay by the production of a spit or bar. The descent of the terrestrial alluvia being checked by the tide, a bank is produced, which gradually raising itself above the waters, becomes dry land; continuing to receive accessions of materials on the interior side, and often on both. If the entrance of a powerful river, united to a peculiar form in the shore, determines a rapid increase of the land at the aperture, its channel may at length become so narrowed and prolonged through the bar, that the further entrance of the sea is checked; and thus a fresh water lake is the result. This occurs in the Crimea, according to Pallas, and in the Gulf of Mexico; while, in our own island, the whole process can be seen, from the commencement to the termination, in different places. The long transverse spits of the Gare loch and Loch Fyne are examples of the first stage: at the Connel ferry and Balahulish, these spits have become plains; leaving, at the latter place in particular, but a narrow passage for the water: while, whether the ultimate result will ever happen in these places or not, it has taken place in a small lake near Cape Rath, now occupying what was once a salt bay.

Of antient unknown Currents

Whatever imagined facility may be afforded by such currents in explaining geological phenomena, it is an hypothesis which has been rendered repugnant by its

abuse: having been adopted even to explain the directions and forms of mountains, consequent as these are on the nature of the rocks, and the positions of the strata. When all the ridges of the earth were supposed to lie in one direction, it appeared simple, at least; though we may wonder at the hydràulic knowledge which first produced these currents, and could then assign the enormous destruction of solid rock to this cause. In cases innumerable, no imaginable system of oceanic currents could have produced the effects; as, in many more, there should have remained other traces which do not exist: but as an examination of examples would lead to great length, such enquiries must be trusted to those who are more willing to investigate truth than to establish a theory, and who possess, at the same time, that geographical eye, and that accurate and extensive geological knowledge, which are indispensable in such cases. The vanity of explaining every thing has ever been the bane of knowledge: while it is seldom considered how often it is the proof of ignorance. He who knows much, has no fear of stating what he does not know: whereas he who knows little, pretends to every thing, because he knows not where he may safely confess his ignorance.

Because the excavation of valleys has been referred to this cause, by geologists of such reputation as Saussure, I must enquire of the matter, though the result cannot be creditable, either to him or his followers; least of all to those of mathematical attainments. If there are cases where the action of some such cause is probable, its power has been often unwarrantably extended; while, in many valleys, it could not have produced the required effects, or should have left other traces. It is not unusual for many valleys to diverge from one point, for two to separate in opposite direc-

tions, or to meet at right angles; or for a single valley to be bent, so as almost even to return towards its origin: all of them being cases which no such currents could have produced; while the simplest case of all is perhaps the most striking. A longitudinal and straight valley originates by a shallow sinuosity, enlarges to a ravine, subsequently to a glen, then becomes a wide open space, and lastly terminates in a plain. It is impossible to imagine a sudden current to produce such a form, nor what its direction could have been. If from the summit, here is a force, and a body of water, which commence as nothing, terminating, after a progressive increase, in any quantity that can be assigned. If in the opposite direction, the difficulties are such that it really is trifling with a reader to state them; and as, in either case, the mass of water is the same through the whole stream, its corrosive power is most exerted where it ought to have acted least, and the reverse. The case of longitudinal valleys opening at the sides, presents another difficulty equally insurmountable. If that of the Dorea has been quoted as an instance, Loch Awe presents one equally striking. There is no possible mode in which a "diluvian current," could have sought and formed a lateral exit through that deep and narrow pass which now gives passage to the Awe. Valleys which have an opening narrower than themselves, and those containing lakes, where the bottom is lower than the exit and the entrance, are all equally inexplicable on this supposition. The force supposed to have excavated the wide valley of the Tay, could not have left the passes of Craig y Barns and Birnam what they are now; as Glen Lyon could not even have existed under such a cause; while the depth of Loch Ness is a sufficient objection, in itself, to the production of the great Caledonian valley by such a power.

It is impossible to assign the mere mode of action in these cases, supposing the general fact admitted. Were such a current now directed against the opening of any given valley, no greater portion can have acted than what was equal in breadth and depth to its transverse section: and, thus, even at the commencement, it is required to open for itself, in one only spot, a parallel, or a dilated, or an enlarging, or a diminishing channel, often of many miles in length. It is sufficient to suggest the impossible progress of such an operation at the great Caledonian valley, or in that section including Glen Tilt, which stretches to Brae Mar. I need not proceed: if any one can produce unexceptionable cases, they must be believed: but none has yet been produced, and I know of nothing, even analogous, unless it be the sudden failure and discharge of a lake; while every such current must have been too brief to produce much effect, as also that could have been but some enlargement of the previous valley, and scarcely of more than was alluvial.

But I must not omit one argument supposed to afford a strong evidence, of such "diluvian" currents; namely, the scratches or marks of friction, already noticed on rocks where water does not now flow. Many of the quoted instances occur in places where rivers have once run, under the changes already pointed out; while if the others confirm the former existence of currents that could not well have been rivers, they are not competent to prove such movements of water as I have here rejected. I shall enquire further of them presently, as the probable effects of heavy alluvia transported by water under other causes.

If I need not repeat, that these imaginary currents have been derived from visionary notions of some early conditions in the ocean, so shall I not enquire further

about hypotheses resting on such knowledge and talents as have been displayed by the Kirwans and the De Lucs. They are portions of dreams that will be sufficiently examined hereafter: my present business is with facts and evidence, not with anile conjectures. When La Place shall tell me that such things have been, it will then be time to enquire what they have done. If other evidence of such currents has been imagined, in the waste of sea shores, here also I see nothing but the tedious effects of daily actions; as I leave to another set of theorists to produce them by "convulsions of nature." I know not why we must believe that England was ever joined to France, at Dover, because both shores possess chalk cliffs: if these are to be our conclusions, whence are there any islands in the world? If it be that Britain was peopled with animals at an early period, why is New Holland thus peopled, or how came plants on St. Helena? This is but another form of the theory which will not permit even mountains and valleys to have been produced by the original elevation of the strata.

I have not thought it necessary to bestow a separate section on the destructive powers of the sea, and it is perhaps best examined here; since it will at the same time answer this speculation. The evidence is every where; but the causes are those already discussed; and a just examination of the facts will prove it to be so. The cliffs of rocky shores fall, for the same reasons that those of the interior mountains do; the sea carries the materials away, after it has pulverized them, just as it removes the alluvia of rivers; and as far as itself aids in this destruction, it is by the force with which its waves, aided by these fragments, assail their bases. There is no stream of the ocean which can, of itself, wear away a rocky shore; and that which is now, is

that which was. I have no doubt that the chain of Isla and Jura was once continuous; and still more certainly was it so on each side of Scarba. It gives passage to a tremendous tide: but that tide could no more have existed before the breach was made, than could a terrestrial current have assailed the side of a wall of mountain and made a passage through it. While that chain was one, the tide current, any current, flowed between it and the land, as it was diverted by that barrier; but it found some breach or fissure which a stream had made, and forcing its way by degrees, it produced Coryvrechan. It is but the river and the ravine in another form: the tide sought the shortest passage to restore the equlibrium, and the rest followed. The very germ of the whole process may be seen at Seil, where a bridge yet connects that island with the main land. That passage will long be little more than it is now; but when once the tide current shall find a free opening here, the separation will proceed rapidly, and the geological posterity which never heard of this bridge may agree that Seil was insulated by Mr. Kirwan's currents, or by "The Deluge." It is valuable to find such evidences of this tedious procedure as cannot be questioned, and they are much oftener to be found than geologists discover. The waste on the west side of Shetland is enormous; and it would be easy enough to quote it as an instance of the effect of oceanic currents or other brief violence. Yet the Drongs, rising in slender pinnacles more than a mile from the shore, and to the height of a hundred feet, remain, a portion of that granite vein which can be traced on the land, and marking the gentle and slow efforts by which the including rocks were removed. I trust that I may dismiss these imaginary currents also; since I need not produce the thousand

other similar evidences existing all over the rocky coasts of Scotland.

There is perhaps no more satisfactory proof of the disjunction of islands from the main, than the existence, on them, of alluvial matters or fragments derived from rocks which they do not contain. The granite blocks on Lamlash, peculiar as that granite is, demonstrate its former connexion with Arran. Staffa, containing fragments of rocks not found even in Mull, must once have been connected with the mainland itself. But had these islands been disjoined from the main by powerful oceanic or "diluvian" currents, the alluvia must have been swept away; nor can this be evaded by saying that they were then deposited, since they often occupy places where it is impossible that they could have rested under such circumstances. Hence then, again, we must attribute these disjunctions to that gradual action of the sea, of which the evidences are every where, and no where more striking than in those enormous walls and prolonged dykes of trap, hereafter noticed under Denudation.

But there is a rational view of the causes of currents, or great movements of water, in the early condition of the present earth; while, if not actually proved by any effects that can safely be assigned to them, they must be believed in, because they must have been. This cause was the elevation of the strata: but thus, instead of any general current, or system of currents, from fanciful causes, there must have been numerous partial and irregular ones, differing also in time, as this work proceeded, even down to those days which elevated Italy and Owhyhee. We can imagine such events producing almost any complications of simultaneous and successive effects, with any intricacy of consequent results that can be desired, and with powers competent

to any thing that water can be proved to have effected: but I know not that we can yet point out such an effect connected with its cause, and perhaps we never shall. If any doubt could possibly remain respecting such a cause, the very effect and the cause together have occurred repeatedly in our own times, if on a limited scale; in Calabria, in Jamaica, and elsewhere: the sweeping wave of an Earthquake is the current in question. And in this necessary course of former actions, we shall probably find the true causes of such alluvia as cannot be attributed to rivers or other existing ones, and which have so often been attributed to "The Deluge," as I shall more particularly show when speaking of the Alluvia in a future chapter. The subversion and fracture of the upper strata during elevation, is precisely that which would facilitate the action of such currents, or waves, on them; and thus can we easily conceive large bodies of alluvia carried forward to some point of rest, and, where that point was supramarine, remaining to disclose the history of former times.

With respect to currents or deluges arising from the temporary enlargement of rivers, it is easy to reason on their effects; since their direction can always be assigned, and as they can also often be proved by particular appearances, and by historical record: while, where such a probable cause can be inferred, we need not have recourse to hypothetical ones. Yet I must repeat, that the presence of alluvia at a higher level than the actual bed of a river, is not evidence, even of inundation; as I have also shown whence it arises. In mountainous countries, such deposits from occasional inundations doubtless occur; but, the greater number, when carefully examined, will prove to be

those of the torrent when at a higher level or in a different situation.

The last source of currents of which I am aware, is that casual and sudden drainage of a lake already noticed. It cannot easily occur more than once in any place, though Glen Roy is a noted instance to the contrary, while its effect may be what is termed diluvian, in every respect. But as the source and direction of the water are here also known, and as its bulk and velocity may often be estimated, it can seldom be difficult to assign the true cause of any effects occurring in such a vicinity. And if a lake can scarcely be filled by deposition, without being also partially drained by the lowering of its barrier, the results may be complicated, while generally depending on the comparative rapidity of the two processes. It has been a favourite speculation, as old as Strabo, that the Black Sea broke loose at the Bosphorus in this manner, and that this event was produced suddenly, by the action of earthquakes; but no consequences of such a supposed deluge have yet been pointed out. If the drainage of the plain of Thessaly, already noticed, was effected by persevering efforts of the river of Tempe, it could have caused no such results. That Glen Roy produced three successive deluges, can admit of no doubt; but while I refer to the original paper (Geol. Trans.) to show, at least, that the subject was not neglected, under any view, or any needful preliminary theory, I have never been able to trace any effects which could be attributed to a current or deluge, though the discharge of water must have been very considerable. And thence also must I receive with great caution, all reports which attribute deposits of alluvia to such a cause; while, of those which have been thus assigned,

to any thing that water can be proved to have effected: but I know not that we can yet point out such an effect connected with its cause, and perhaps we never shall. If any doubt could possibly remain respecting such a cause, the very effect and the cause together have occurred repeatedly in our own times, if on a limited scale; in Calabria, in Jamaica, and elsewhere: the sweeping wave of an Earthquake is the current in question. And in this necessary course of former actions, we shall probably find the true causes of such alluvia as cannot be attributed to rivers or other existing ones, and which have so often been attributed to "The Deluge," as I shall more particularly show when speaking of the Alluvia in a future chapter. The subversion and fracture of the upper strata during elevation, is precisely that which would facilitate the action of such currents, or waves, on them; and thus can we easily conceive large bodies of alluvia carried forward to some point of rest, and, where that point was supramarine, remaining to disclose the history of former times.

With respect to currents or deluges arising from the temporary enlargement of rivers, it is easy to reason on their effects; since their direction can always be assigned, and as they can also often be proved by particular appearances, and by historical record: while, where such a probable cause can be inferred, we need not have recourse to hypothetical ones. Yet I must repeat, that the presence of alluvia at a higher level than the actual bed of a river, is not evidence, even of inundation; as I have also shown whence it arises. In mountainous countries, such deposits from occasional inundations doubtless occur; but, the greater number, when carefully examined, will prove to be

equally misapprehended and misapplied, that which rests on the credit of the Sacred Writings, have written to injure the cause which they professed to support. If The Deluge was produced by other secondary causes than those delivered, we cannot discover them, nor are we required to do so: even though there is one, which, if stated as a physical fact, we do not comprehend. To us it is related, as a miraculous interposition of Providence, for declared moral purposes. The same Power, for other ends, divided the Red Sea; and though here also, there is a Secondary cause assigned in the "East Wind," no mathematician will attempt to investigate the power of any wind to produce such an effect, or, consider it as aught but the immediate act of Him who established and controls the laws of nature. Thus to scan all the miracles of Scripture, would be to renounce all that we believe on those grounds which are the foundation of our faith. Thus, imaginary causes of the Deluge are properly struck out henceforward, from the considerations of geological science; as I presume will now at last be admitted by every one.

Now, respecting its possible effects in producing the phenomena ascribed to it, we must be guided by the information afforded us respecting its nature. We have no right to add any thing to what we have received on this head: it is painful to think that they who have most indulged in unwarrantable attempts of this nature, ever deemed censurable in analogous cases, should have been the first to bring forward charges of impiety against those who were content simply to receive that information which the sacred historian thought proper alone to communicate. In this plain narrative, the water rises during a short

period, and subsides through one not long, leaving on an eminence, that vessel which was to preserve and perpetuate Man.

It is far from pleasing to be compelled thus to dissect Scripture, and on a subject of a purely physical nature. Yet it is to defend it from pernicious intrusion, to say that where it is simple, plain, and intelligible, it must be taken simply and plainly. There is nothing in this history from which we can infer a state of turbulence or violence in the water. There is nothing to make us suppose that the Deluge could have disjoined islands, excavated valleys, or deposited alluvia. It is deficient alike in the two needful powers, motion and time. Of the former in particular, and to the extent and velocity required for such purposes, no mathematician can contrive the means: but they who invent such hypotheses have rarely knowledge enough to perceive their own wants: while in this case, where a single purpose is declared, and declared to have been executed, and where also that only purpose could have been perfectly executed in the tranquil manner which must be inferred, the Almighty is asserted to have done infinitely more than He has declared, and for no end that can be conceived. If this be not that daring perversion of Scripture to which a very harsh term is applied, if it be not to assume a certain conduct in the Deity because we desire it for our own ends, and this too by those who profess peculiar reverence to Him and His scriptures, while they persecute the simple followers of His word, I know not well who can deserve the censure of wantonly misinterpreting the Sacred writings. The Ark was scarcely a structure to have lived on such waters as this geological speculation presumes; or, if miraculously preserved amid such unnecessary commotion, to have settled in the

very regions where it was constructed. Nor could the torrents which demolished mountains throughout the wide extent of the globe, have left a leaf on an olive; while to suppose that this also was miraculously preserved, is but to invent a human romance of involved miracles, to serve a fanciful and unnecessary purpose. Were we even to speculate on what must have happened, though not narrated by the Sacred historian, we could add nothing to his account but the Tides. Under their influence the waters of the Deluge must have remained; but, even thus, they were inadequate to produce any one of the ascribed effects, since we know how limited they must be in an earth which is all ocean. Let us contemplate this subject as we do all else in Scripture: and not attempt, by misapplied reasonings, to interfere with that, of which the Deity has condescended to communicate all that was necessary for the moral ends alone in His contemplation. But as, in such questions, the authority of a Theologian carries a weight which is refused to the opinions of mere Science, it is Burnet who remarks that "'Tis a dangerous thing to engage the authority of Scripture in disputes about the natural world, in opposition to reason; lest time, which brings all things to light, should discover that to be evidently false which we had made scripture to assert." If that prophecy has now been fulfilled, it is he also who quotes the parallel opinions of St. Austin on the same subject. "Cum enim quemquam Christianorum in ea re quam optimè norunt errare deprehenderint, et vanam sententiam suam ex nostris libris asserere, quo pacto illis libris credituri sunt de resurrectione mortuorum et spe vitæ æternæ regnoque cœlorum, quando de his rebus quas jam experiri, vel indubitatis numeris percipere potuerunt, fallaciter putaverint esse conscriptos."

On Denudations.

Though I have enquired of such destructions of land as are obviously dependent on assignable currents, there are other appearances of this nature, for which it is difficult tò discover a cause. These have been called denudations. But as this term has been applied to every marked loss of land, under whatever cause, I must here limit myself to those of unknown or doubtful origin; merely suggesting one or other of the known causes, where such explanations seem admissible. It is easy to suppose that every ridge or peak has been thus produced, or shaped: but the former remarks on the elevations of strata, show that such a principle must be cautiously adopted and carefully limited. In countries of trap, however, where the masses are horizontal and the subjacent strata at low angles, we find summits of that rock separated from similar ones, or from larger tracts, in such a manner as to indicate the removal of the intermediate land. In Scotland, the instances of this nature are so abundant that it is unnecessary to specify them: though I shall have occasion to notice one of the most remarkable immediately, in Morven. Where conical detached mountains are formed of strata at low angles, the same explanation must be given; and the loss of land is inferred in a similar manner, by the correspondence of the distant portions. The most remarkable instances of this nature, in our own island, occur on the western coast of Rossshire. Here, a complicated group of mountains, consisting of nearly horizontal sandstone, is based on gneiss and shaped into independent masses and cones, with intervening chasms and valleys, or extensive open tracts, of mere gneiss, often of many miles in extent. And while, through-

out this wide space, the base varies in height, or undulates, so that the lower portions of the sandstone occupy different levels, the summits of all the mountains range at an average general height of about 3000 feet. Among these, Ben More forms a solid and extensive mass; while Coul beg, Suil veinn, and others, the first a mere peak, are separated by many miles from all the other portions. It is impossible to avoid inferring that a continuous bed of sandstone once covered the whole: the divisions of the strata in these separate mountains corresponding accurately in level, while no instance of a position more angular occurs; and the summits, every where, bearing the usual marks of waste. They have all therefore been shaped out of a continuous mass; or the intermediate country has been denudated, and that to a great extent.

This kind of denudation is, in other cases, rendered sensible by the correspondences of peculiar strata, in a particular order, at considerable distances. Thus, at Pittsburgh in Pennsylvania, whatever the cause may there have been, coal is found occupying distant summits, or opposite sides of a valley; but we need not go further than our own islands for a very striking instance of this fact. In Morven, several mountain summits of gneiss are covered with insulated masses, consisting of slender portions of secondary horizontal strata with coal, surmounted by trap; the whole having been evidently connected, before that land to the loss of which they owe their present extraordinary position was removed.

In other instances, we find indications of similar losses, without such marks of the spaces and depths they once occupied. In such cases, the denudations are sometimes inferred from the absence of the superficial strata in a particular district, when they are pre-

sent in a neighbouring one; but the conclusion is much strengthened when we see tracts of loose materials that have been produced from their destruction. Thus the dark brown trap soils of the central parts of Scotland, prove the former existence of such rocks in those places: while, when small and detached portions of the rock are found scattered about a country, bearing such traces of decomposition, the certainty becomes almost absolute; and thus also are we enabled to approximate, at least, to the former depth as well as extent of the rock which has disappeared. In the same way, we must believe that the saline sands of the several Deserts are the produce of that "red marl" which still exists in a sufficient number of places to indicate thus much, at least, of denudation in those countries. I need not now, I hope, answer the speculation of a well-known Theorist, which asserts that these are the unconsolidated bottom of the antient ocean. Similar also are many cases of alluvia foreign to the substratum, found on gneiss and other rocks; marking equally the denudation of which they are the remains. Among these, are the alluvial gravels which have often been attributed to transportation, antient or recent, as the theory of each observer inclined him. The different cases may not always be easy to distinguish: but, unquestionably, many of them are the remains of rocks which have been demolished under some process of denudation. Such, probably, are the gravel beds of England: but this subject is more particularly examined in the chapter on alluvia.

England seems to present many indications of that denudation where the loss is so complete that no traces of the strata remain. This at least may be inferred as to many of the upper ones which we might expect to find, where there is nothing to indicate that they

were not originally deposited in those places as elsewhere. It is proved, among inclined and incurvated strata, when the outer and lower beds are wanting in a tract of concave strata, and the outer but upper ones in a convex series. Thus, at Crowborough hill in Sussex, the strata above the ferruginous sand are deficient on each side; while, near London, the deficient strata are those beneath the clay. Although in England, in many places, a great depth of stratified rocks lies above the coal series, they disappear in Scotland; whence, in that country, it is almost every where uppermost. We cannot indeed prove that it has not always been so; but from the great loss of strata in this part of the island, the contrary is most probable.

There is one evidence of denudation, which, though limited to a few tracts, demands notice, especially, here, from indicating a cause which has been either unsuspected, or to which very inferior powers to that which it possesses have been assigned. This is the persistence of Trap veins, much more rarely of granite ones, after the surrounding strata have disappeared: thus remaining an index, if not a measure, of that waste which their harder nature has enabled them to resist. Near Comrie, two of these, of great dimensions, hold a parallel course for many miles, rising high, in many places, above the surrounding land; and, in the great Cumbray, one not less remarkable from its curvature than its elevation, crosses the island; a magnificent wall from the hand of Nature, and a beacon of the waste which the including sandstone has experienced. A similar one in Isla, holding its uninterrupted course over hill and valley, produces, at first, the deceptive effect of some gigantic work of architecture. But none are so striking as that great wall of pitchstone which forms the Scuir of Egg; a deserted vein, indi-

cating the destruction of the surrounding land, and to a depth which, in some places, reaches to six hundred feet; while the total loss may well be much more, unless we could suppose that the vein itself had undergone no vertical diminution. All these, and more that I might name, indicate that cause which I shall immediately attempt to assign: the following instances are but proofs of that tedious action of the sea which I have already examined. I note them here, for the purpose of teaching young geologists the necessity of attending to causes, in reporting identical appearances. From Loch Craignish northwards, the shore is crowded with them, projecting towards the sea, like huge walls, and sometimes reaching to a hundred feet in height. In Sky and in Mull, they are still more remarkable; being covered, in the latter island, with ivy, and giving root to shrubs and flowers, so as to resemble those ruins of antient castles which occur in similar situations.

In some countries, certain tracts appear to have suffered more from this process than others, though no obvious reason can be assigned. Such seems to be the case in many parts of England; but that portion of Scotland which is included between the Murray firth and that of the Forth, shows it in the most striking manner. The great trap range of the Campsie and the Ochils, begins to show marks of waste as it passes Perth; while, in advancing further eastward, it gradually vanishes: the marks of its former extent remaining, in the indications already mentioned, as far as Stonehaven and Montrose. Thus also, in Aberdeenshire, the stratified rocks are removed down to the surface of the granite; as if this part of the island had been exposed to some causes of destruction from which the western was exempted.

If I need not illustrate this subject of denudation by

further examples or varieties, it remains to enquire into the causes which have been assigned for it. The ordinary action of running water on the surface is the first and most obvious of these. So great, it is said, have been the changes of the surface since rivers began to flow, that we can scarcely say where they might not have flowed, or what they might not have destroyed. Yet I know not by what possible system of waters, in any state of our island which can be imagined, the sandstone mountains of Rossshire could have been cut out of a solid stratum. It is equally impossible, on this principle, to account for the peculiar denudation of the east side of Scotland, where the present rivers, under any imaginable former búlk, or under any changes of place, seem insufficient for this purpose. It is not within my plan to examine visionary causes. Appulses of comets, or whatever else, must be sought where they are to be found, by those who seek what I do not: the present pursuit is Knowledge. I do not however see how some of the appearances in question can be explained by aught but currents more extensive and powerful than any rivers could have produced: while, as to other cases, it must be left to the observer himself to apply this solution to those in which he may think it adequate, as it probably is in that of Pittsburgh, just quoted. But, of such currents, I can say no more than I have done already. I can discover no reasonable cause for them but the elevations of strata; while those accumulations of alluvia which are inexplicable under any conceivable system of rivers, may often indicate the direction of such a current. Yet even this gives us little assistance, unless we can explain how a current of this nature, even aided by stones in motion, could effect, on whole mountains, in a very limited time, what a mountain torrent, surely not less

powerful within its confined range, requires ages to perform on a narrow line of surface. I believe that this is long likely to continue one of the greatest difficulties in Geology.

The decomposition of strata *in situ*, and the tedious action of rains, producing a gradual flow of water on the surface, will probably account for many of the denudations which occupy large spaces without extending to great depths: such as those which occur among the strata of England; while also, as I believe, they account for many more. To that preparatory cause, however, must be added the usual waste of rocks through atmospheric agencies: and, if I mistake not, the great denudations of Trap in Scotland can be explained in this simple manner. That it is a great power, though tedious in its effects, I have already said; and if it be that which has lowered Egg, for example, I know not what it might not effect. Nor do such cases admit of any other; because the remaining veins, or protruding rocks, of whatever nature, are often so slight and feeble that no power capable of removing the surrounding land quickly, could have left them standing. The great vein of Cumbray, formed of transverse columns which the human hand can remove, could not have resisted the least force of water, nor could the Cheese-wring of Cornwall. The power in question is indeed feeble, as the action has been tedious; but it is never-ending, and it is sure; as it is the very agent provided for a great Final Cause, the perpetual renovation of Soil. And if we witness it in these cases, so do we in others, where a summit of some harder rock, or even an insulated and casual stone, will often protect a whole cone of feeble land, where a neighbouring portion, not thus guarded, is wasted away. Having thus the most absolute demon-

stration of the power, and the very great power, of this most simple cause, so much overlooked, we may safely apply it where no such evidence remains, and thus admit Rain and its consequences as one of the great agents in denudation.

I can suggest but one more cause, and it is connected with the present one. If it has a hypothetical appearance, it is consistent with the laws of philosophical Theory to suggest probable consequences from causes that can be inferred, though not proved. The reasons have long since appeared, for a state of heat in the waters which must have been attended by an extravagant evaporation; while the results have been admitted very generally, though I may suppress all that has been said respecting a chaotic atmosphere. Corresponding descents of rain must have been the inevitable consequence; while something analogous occurs in the case of volcanic eruptions: and thus is there a power capable of producing the same effects, but to a far greater extent; as it is also one which aids in solving many of the difficult facts relating to alluvia. If I did not suggest it formerly in speaking of Currents, it is that I reserved it for this fitter place; while I need not say how it can be applied in aid of those causes of great movements of waters on the surface of the Earth which have been already suggested.

On Changes in the Depth and Level of the Sea.

As the outline of the sea varies, in consequence of the transportation of the land, so does its depth. But as our means of determining that variation are limited to the shores and the shallower seas, we are unable to trace that distribution of the marine alluvia along the bottom, which can however often be inferred from circumstances. Though much of the materials brought down

by rivers is deposited at their entrances, much also is moved to greater distances, by the influence of tides and currents. This takes place principally with the lighter materials, the finer sand and mud; while the work of the waves is to pulverize the coarser deposits, which would otherwise so accumulate as to encumber every sea shore. Losing much of their specific gravity by immersion, and rendered further buoyant by the increased ratio of their surfaces to their bulks, these become very moveable; while their facility of transportation is increased by the declivity of the bottom, on which they necessarily tend to the point of rest. And that these materials do thus travel to great distances from the land, we know from soundings; which, except in occasional rocky ground, always bring up clay, sand, and fragments of rock; while, if we cannot ascertain their depths, the penetration of the lead-line through them has has often been known to exceed twelve feet. If the Dogger Bank is entirely composed of such materials, their depth, in this case, is ascertained to reach to nearly eighty feet. But our imperfect means of examination do not compel us to limit the range of either depth or extent. We know not where the distribution can cease; while, even to twelve feet, time may add an indefinite depth. In the shallower seas, the effects are far more within the reach of examination; and thus it has been computed that the Baltic shoals at the rate of forty inches in a century, an effect, however, of which the true cause is disputed, and that in the Yellow Sea of China, the process is so rapid as to allow a time to be fixed for its filling up. But, the data are rarely sufficient for such conclusions: since the continued transference of the materials renders it impossible to depend on distant inferences from given soundings. Sand-banks constitute the obvious proof of the power of the sea in trans-

porting the submarine alluvia, and in modifying their forms. The changes which these undergo are well known to mariners; as is their gradual increase, from the accession of materials; whence it is, that after the lapse of a few years, they require fresh soundings and buoys, especially in such narrow channels as our own. It is easy to understand how the deposition of mud and sand may be determined by peculiar forms in the land, producing a state of comparative repose at some point; or through an eddy, from the combination of such forms with the tides. Thus is the Dogger Bank determined by the meeting of these, as is that off Cape Rath, and those in the Irish Channel. The Great Bank of Newfoundland is the produce of the Gulf stream; as those off the mouth of the Baltic are produced by the current flowing out of this confined sea.

The greater movements of the ocean appear to be the leading causes of the distribution of submarine alluvia. It is now known to include a system of established currents, mutually connected and permanent. Their important services in equalizing its temperature belong to another department of natural philosophy; but they seem not less to interest the geologist, by producing the effects under review. I may refer to Rennel for the details of that great current which, traced from the Eastern Coast of Africa, passes the Cape of Good Hope into the great ocean, proceeding to the North-west along the African shore, with a breadth which exceeds a thousand miles near the parallel of St. Helena: whence, joining one from the North, they unite and turn to the South-west, upon the American Coast. Meeting at Cape St. Roque with another running northwards, it falls into the Gulf of Florida, producing the gulf stream, which running northward, at length stretches across to Britain, depositing on our islands the buoyant produce

of those countries; when proceeding down the coast of Spain to Africa, it completes that round which maintains a perpetual circulation of the waters throughout a large portion of the globe. If these currents have not yet been thoroughly investigated in other parts of the ocean, there is abundant evidence of their existence every where, with sufficient proof of their power in distributing the submarine alluvia, in the facts already mentioned respecting the shores of Mexico. But this power in the ocean is visible, in comparing those rivers which produce neither islands nor deltas, with those in which these occur. The Congo, the Plata, the Oroonoko, the Maranon, and many others, enter the ocean, deep and bold, unattended by those obstructions which characterize the Nile, the Euphrates, the Wolga, and the Danube; yet they do not convey less earth in proportion, as is evident in the lateral plains which they have produced: while this difference of result must be sought in the ocean currents which the former meet at their junctions with the sea: thus indicating the mode in which the materials, which would otherwise accumulate to shallow their æstuaries, are disposed of. The slightest geographical knowledge will show these differences between the Congo and the Plata, contrasted with the Nile and the Danube: and these obvious considerations, which any one can localize, will explain the various circumstances attending our several European rivers, and the positions of their subaqueous alluvia. That which cannot be at rest in their own æstuaries, must collect in the lee parts of the broader channels, or at the points of repose between tide streams.

A little reflection on the laws which regulate the movements of water in narrow channels and determine the equilibrium in different places, will now show that the form of the bottom cannot thus be changed, without pro-

ducing an effect on the level of the water which flows through it. Hence that of the sea becomes affected in particular channels, and also differently affected in different places. Thus, in rising, it encroaches on the land, while the land, from the causes just examined, is also encroaching on the sea ; a double, and apparently opposite effect, resulting from a common cause, while leading to disputes which a little knowledge might have prevented. Were there no currents or tides, and were the ocean in a state of absolute rest and equilibrium, its level would unquestionably be every where raised by the gradual addition of earth to its bottom and its shores. But, compared to its great depth and extent, this can produce no sensible effect ; and it is therefore to the deposition of earth in tide-ways or currents, that the elevations of the level of the sea are to be attributed ; except, as must be obvions, in the case of an inclosed sea. The truth of this reasoning is confirmed by observation : but encroachments of the sea may also follow from the subsidence of the shores, or from their waste, as must be obvious. In examining different examples of these changes, we may, by attending to these considerations, succeed in separating the different causes whence they have originated ; and thus, often clear the general question respecting the changes of the earth's surface, from the obscurity in which it has been involved by those who would admit only one cause, as well as by those who have confused themselves through ignorance or misapprehension.

But if the chief observed variations in the level of the sea consist in its depression, this expression prejudges the cause : the variation in question being that of the relative position, at different periods, of the common line which bounds the land and the water. Such a change may arise from four causes ; namely,

an increase of depth or capacity in the bed of the ocean, an increase of depth in certain narrow seas and channels, a general diminution of the waters of the globe, and lastly, an elevation of the land. It must therefore be evident, that as there are causes which tend both to elevate and to depress the apparent level of the sea, the effects may often be very complicated, whatever these causes may be. They may neutralize each other in the same places, they may act in opposite ways on different shores, or they may alternate, both in time and place. Hence we may often explain the contradictory testimonies of geographers on these subjects, and perceive also the difficulties in which the observations are involved. A few recorded examples of such changes will suffice for illustration; nor indeed are there many to be procured.

The relative changes of the level of the sea and land on the northern shores of Europe, have been represented, by some writers, as having operated in one direction, by others in the reverse. Celsius first said that the Baltic was gradually lowering, and he was followed by Linnæus, Wallerius, and others; while Von Buch has made the same remark respecting the gulf of Bothnia. This has been denied by Browal, Kalm, Breislak, and De Luc; and hence the testimony of the whole has been doubted by those who admit of no change but the gradual depression of the sea; while I have given reasons for supposing that both parties are right, and that, at different times and places, there have been both elevations and depressions of the sea line. And, that the sea line has, at some periods, risen on the coasts of Holland and the neighbouring country, is confirmed by corresponding observations on our own eastern shores. The submerged forest of Lincolnshire is a sufficient proof that the sea

line is now higher here than it was once; and similar alterations have been ascertained on other parts of the eastern coast, proving, that within a time which cannot however be fixed, the general level of the German ocean has been raised on our shores, and probably therefore on the opposite ones: though, as the land itself varies in height, this does not necessarily follow. But as I shall soon show that this very sea line was formerly higher, there must have been a succession of changes in it, in opposite directions; the first, of which we have any evidence, consisting in an apparent depression, and the last in an elevation of the sea. Thus are illustrated the similar changes said to have occurred on the coast of Holland and on that of Lincolnshire; where the facts prove that the sea formerly reached far inland, while it afterwards retired, to rise again. And this last change, consisting in the elevation of the sea line, is not limited to our eastern coast; if we may trust to similar evidence on the western, furnished by the submerged forests of Mann and Somersetshire.

It is certainly possible that this apparent elevation of the sea may arise from the depression of the land, as appears to be the case in the Mediterranean; but Mr. Playfair, who has principally defended this view, seems strangely to have excluded that cause with which, as a mathematician, he must have been familiar, while otherwise consistent with his views respecting submarine deposits. He very properly remarks, that in an ocean at rest, the sea must find a common level, and no such partial elevation could be sensible; but when he overlooks the obvious hydrostatical consequences resulting from the propulsion of the tide streams through diminishing channels, we can only explain the oversight by an anxiety respecting a fa-

vourite principle. Even hence, he must have known, arises that difference of level between our eastern and western waters, which is demonstrated by the lockage of our Canals.

The alterations of the sea line in certain parts of the Mediterranean have attracted much attention; and no small ingenuity has been exerted to avoid conclusions supported by too much collateral evidence to be rejected. If authors do not always agree respecting the facts, it must be attributed to some bias in favour of their own systems. The observations of Fortis, Manfredi, and Zandrini, show that it is rising; and Manfredi, in particular, has ascertained that the sea line of the Adriatic continued to rise from the beginning of the Christian æra to the middle of the last century. This was determined by the pavement of the Cathedral of Ravenna, now a foot beneath the level of the sea, and by corresponding observations at Venice. The same conclusions have been drawn by Breislak, from some Roman works near Baiæ and Naples, now submerged, though unquestionably built on dry land; consisting in the remains of an antient road, some buildings of the Porto Julio, some columns at the foot of Monte Nuovo, the pavement of the Temple of Serapis, and the ruins of the palace of Tiberius in Capreæ, now entirely covered by the sea. It is also important to note, that in the columns of the Temple of Serapis, pholades have perforated the marble at a height of five or six feet above the present level: and, in the ruins near Monte Nuovo, at an elevation of sixteen feet above the ground. Hence the sea-line, once inferior to the bases of these buildings, has risen to the height of sixteen feet above its present elevation, and again subsided to one inferior to that which it now maintains, while supposed to be again

rising. Thence is drawn the important conclusion, confirmed by the other facts just noticed, that these variations of the sea line are oscillatory or variable.

I need scarcely say that the want of a tide current in the Adriatic prevents us from applying the same solution to its elevation as I have done in the case of the German Ocean, great as are the deposits which it receives. The authors in question have attributed these facts to actual changes in the level of the sea. But in the Mediterranean, this could not have happened without leaving similar traces elsewhere: and thus the cause must be sought in changes of the level of the land; its subsidence being the apparent elevation of the sea, and the reverse. And the perpendicularity of the buildings is not a valid objection, when these changes must have been gradual and extensive. I have elsewhere shown that Italy has been subjected to such changes, to an enormous extent, and that similar elevations occur in the Coral islands; so that it is easy to admit far more limited ones, and these in a territory under the constant action of the very causes in question. There is a natural antipathy to admit of the movements of what we have been accustomed to consider as steady, and of the comparative steadiness of that which we see to be in hourly motion. But let the ocean fluctuate as it may, it possesses a principle, restoring it for ever to that mean state of repose, which the earth, once disturbed, cannot easily recover. If it be true that earthquakes no longer cause surprise in those who have vanquished their prejudices respecting the steadiness of the land, let the Geologist, at least, conquer the same prejudices, and he will then no longer tease himself by searching after every possible solution of his difficulties but the real one.

As the predominant observations, however, show,

that the sea line is, on the whole, lowering, in the places at least where those remarks have been made, it has been concluded, by some, that while the Mediterranean was rising, the Baltic, and the northern seas in general, were falling; and, by others, that there was a general diminution of the quantity of the ocean. The depression of the sea line in the Baltic, as stated by Frisi, amounts to thirteen Swedish feet in the last five centuries. On our own shores, though appearing to be again rising, it once possessed a much greater elevation: and thus marine remains are found in many places far inland, and also far above the level of the present sea. In the Firth of Forth, this perpendicular difference is said to amount to more than thirty feet: the inland part of the submerged forest of Lincolnshire is a fact of the same nature, and similar ones have been observed at Dunkirk and on other parts of the opposise coast. These changes must have arisen from causes analogous to those acting in the Mediterranean; the sea line having been depressed, because the land was raised, not the sea lowered. The sea of these channels could not have been lowered thirty feet, without some general diminution of the ocean; and the marks of this must therefore have been visible in many more places, or perhaps all over the world. I need not dwell on a solution so simple, and supported by so many other facts; but I must remind the reader of the connexion between these vacillations of the land, and the phenomena belonging to some of the tertiary deposits; while they prove what I formerly suggested, that even at considerable vertical elevations above the present ocean, many of those to which vast mystery has been attached, may be only the bottom of the present sea; demanding none of those imaginary "retreats," and so forth, with which vain speculators have encumbered themselves.

If the island of Banda is gradually rising, as the natives, unperverted by Geological theories, believe and assert, the general fact can admit of no doubt.

Thus, then, in the first place, there is no reason to suppose any falling of the sea in the north, and rising in the Mediterranean, depending on some mysterious cause, or on any which concerns the whole ocean; while there is, equally, no reason to suppose a diminution of the quantity of the sea. To suppose that the bottom of the ocean has opened and engulfed its waters, that the Mediterranean and other seas have once been enclosed at higher levels, and that, by the failure of their barriers, the general level of the ocean has been altered, are dreams as gratuitous and unnecessary as they are clumsy and inapplicable. Equally speculative is the notion that the mass of water on the earth is diminishing. Every atom of that which circulates through the great laboratory of Nature, returns to its parent bed, except that alone, perhaps, which is embodied in peat; nor were all this, and millions of times more, restored at this moment to its original state, could it make a sensible difference in the bulk or level of the sea. I need only add, that the argument as to the general diminution of the sea, derived from the elevations of the Coral islands, is nothing; since I have explained these in a much more satisfactory manner: while the theories of Tertiary Deposits, which have been founded on the same supposition, cannot now require an answer.

General Conclusions.

I have thus examined the principal changes which the surface has undergone since the commencement of the present earth, and is now undergoing. And if the latter depends chiefly on the action of rains and

rivers in transporting the fragments of rocks from higher to lower levels, the great result is, that the mountains tend continually to the plains, and, ultimately, to the sea, thence never to return. If these actions constitute an intricate series, of which we see but a small portion, yet, from their accumulated effects, they who have imagined the beginning, may also indulge themselves in predicting the end. As the general declivity diminishes, so does the ratio of destruction; and thus has it continued to diminish from the moment when the rivers first began to flow. But as the inequalities of the earth waste away, so will ages be hereafter required to do that for which years once sufficed. Yet we may still imagine the ultimate ratio; that point at which the forces of destruction and those of resistance shall be balanced. This is the speculative period at which the earth will become a plain, when the altitude of the land will scarcely exceed that of the sea, and the channels of rivers shall refuse to conduct their waters. Offensive marshes and arid sands will then take the place of this fair variety of hill and dale, and the last chaos will be worse than the first.

This is the natural death of that earth which we inhabit; a lingering decay that must strike with a death equally lingering, the races of vegetables and animals which now possess it. But it is an event to be contemplated only by the imagination. We have no reason to look forward to what rests on a partial view of this beautiful system; a system displaying the goodness, not less than the wisdom of its Author; teaching us how He educes good from evil, how He brings order out of destruction. We ought not to believe that such evil was within His plan; and if we thus reason on the old age and decay of the earth, so do we

perceive that scheme of beneficence, by which it appears to be ordered that this event shall not happen.

I have already shown that successive revolutions had occurred, long before the mountains had been levelled: while still the earth retained those inequalities without which the rains could not have been conducted to the sea, without which they would not even have descended as they now do, on the earth. In no instance, have we reason to think that the natural decay of the existing system had taken place, that the earth was rendered unfit for the habitation of animals before its subversion, or that its races had been gradually suffered to expire as the world was decaying around them. Our own earth will never therefore arrive at the possible state contemplated in the preceding paragraph. Long ere that, we have reason to expect that violent death of the present system which every consideration shows us to be the most beneficent, and by means which our knowledge of the past enables us to assign. And as analogy teaches us that this event will take place while the machinery of the earth is yet unimpaired, so it informs us that the catastrophe will be violent and complete. Let that day come when it may, we have reason to think that it will terminate the existence of all the races of terrestrial beings. This we may believe from physical analogies alone: by inferring the progression from the precedence of a series of similar and concatenated events. Thus Geology confirms the important truth, that the destruction of the world, in which we are taught to believe, is physically probable; as it also teaches us that it is one out of a great series of similar events by which this globe has hitherto been regulated. The former revolutions are the types of that which we are ordered to expect; nor is it difficult to imagine what the nature

of these catastrophes has been, and what the coming one will be.

In a moral view, that Last Day is a special act of the Divine interposition. Yet as the final catastrophe of this our earth is but one out of a number of preceding and similar events, we are entitled to conclude that it will be effected, like the past, by secondary causes, by powers which have been prepared from the beginning; and which, if they are beyond our comprehension, are no less ordained than those which regulate the motions of the Universe, but which are under the command of Him who governs as He created. Truly does Newton say, what all who ever thought seriously, have thought not less than he; that "the growth of new systems out of old ones without the mediation of a Divine Power, is absurd:" but they who quote him whom they cannot read, and on subjects which they do not understand, to prove that no secondary causes have acted in the formation of the Earth, have forgotten that Newton himself sought for a secondary cause of Gravitation. If, when he called it "unphilosophical to pretend that this earth might rise out of chaos by the mere laws of nature," he intended what his ignorant commentators suppose, not even the name of Newton can be authority against facts, and, above all, on a subject which he did not know; were it not even opposed to all that we see of the proceedings of the Deity. The world *has* arisen "out of chaos" more than once, and by the "mere laws of Nature:" but He who created Nature created its Laws; and He who appointed them upholds them daily, and commands them to act as it pleases Him. There is no collision between the purrest Piety and the soundest Philosophy: it is they who pretend to the one, and possess not the other, who are the bane of both.

Geologists have been accused, and justly, of improperly mixing their physical enquiries with the history of the earth as delivered in the Sacred writings. But this is because they have attempted to account for that which lies beyond the reach of investigation, and also to explain it by evidence equally misapprehended and misapplied. This is alike injurious to the cause of Religion and to that of Philosophy. But a juster view of the nature and limits of Geological science, is subject to no such censure. Abandoning all pretensions to explain the inexplicable, and to reconcile the irreconcileable, it is content with tracing the series of visible causés and effects, with pointing out analogies, and indicating the inferences to which they lead. This is far different from that ignorance which would fain prove the truth of Scripture by physical evidence, or the weakness that would found a system of natural philosophy on the Sacred writings. The preceding subject, with a future renovation of the Earth from the materials of the present, is not beyond reach of human reasoning, until it can be shown that the past history of the Earth is a vision. And if such a catastrophe be essential to the total welfare of the earth and its inhabitants, one among the laws which regulate the government of the Universe, if it is that act of mercy, not of vindictive justice which I have shown it to be, bespeaking, like the more ordinary course of nature, the goodness and the wisdom, not less than the power, of the Deity, then does Geology serve the cause of Religion through its own powers, instead of meriting the ignorant persecution which it has experienced from the fanatical ignorant. Let the censure be directed to those who have taken improper views of it. The study of nature will never lead to impiety; nor can Truth ever oppose Truth: the more the universe is examined,

the more shall we learn to reverence Him who regulates the whole.

But there is a long train of intermediate changes, between the first and the last stages of this Globe: constituting the progression of the Earth, and indicating, much more demonstrably, these attributes of the Author of the Universe. They have formed the subjects of this chapter: but I should neither do justice to Geology, nor perform that duty which all Natural history owes, if I did not, though but briefly, show how they illustrate those.

I have shown in the last chapter, that the constant augmentation of limestone in the present earth will become the cause of a better subsequent one; as I have traced, in all its preceding history, a steady progression onwards, from a worse to a better state. But that which is true of its successive forms is equally true of each condition. Every new Earth is better than the preceding; but every new earth is also better at its termination than it was at the commencement. I argue this from the history of our own: and that is the history to which I must now recur, under these views of the Conduct of the Deity respecting Man. Yet are these the ennobling views of Nature and its Great Author, which ignorance and fanaticism would oppose,—if they knew them—and which they impede because their minds are too narrow to comprehend the least part of the works of The Incomprehensible.

The present Earth is enlarging in extent and improving in fertility: thus has it progressively enlarged and improved since the day on which it was first arranged: and thus will it continue to enlarge and improve till the period of its destiny shall arrive. And the physical history of the Earth is the Moral history of Man: while even Man himself becomes, in the

hands of his Creator, a secondary cause to aid in this progressive melioration. The barren mountain generates the fertile plain: the solid earth itself, which must form the dwelling place of Man, is enlarged, and that rock on which he must have perished, could he even have been produced, becomes the source of his increase and of his happiness. And does not Man too here aid himself? moved by that force which his folly has thought an evil, but which He of all Wisdom has appointed, to continue His own plans, and to add to the happiness and numbers of His Creation. America, New Holland, Siberia, will tell us what the earth was without man, what it would have been without the toils of man. What we cannot do, He, who knows and does what is right, does for us: the rest He has wisely left to ourselves; and the result is the Earth which we see, which our posterity will see a far other Earth than it now is.

It is true, it is an unfortunate truth, that man tends to multiply beyond his means of existence: but let it not be said that this has not been provided for, as it was foreseen; if, as of course, under that system which ever leaves contingent evil attached to provisions for good: while, in this case, as perhaps in all others, the very occurrence of the evil is, like the wants of man, the only stimulus by which he could have been induced to carry on the great system of improving the earth in that department appointed to him, and not appointed beyond his powers. If the habitable and fertile earth does not increase with the rapidity of man's increase, still is it ever increasing, as it ever shall; and thus is provision made for the extension of his race. Can any one believe that this also was not within His contemplation, that it is not a portion of a plan alike beneficent and wise?

And is all this effected without the visible exertion of Power? It is; but to him only who cannot see what He is doing, to him who looks on the course of nature as chance or necessity, and to him who, in seeing the power of secondary causes, forgets the First. The preceding history of the earth teaches me another lesson: and may I not be exempted from detailing the beautiful system of machinery by which this system is carried on? in the chemical provisions by which the rocks are hardened that their destruction may be gradual, and by which they are subjected to decomposition from the most apparently feeble causes; in this and more, and in that eternal circulation of water through which the remainder of this great process is effected. It is best that the reader should reflect for himself; for thus will he learn to feel what he who reads forgets to think of.

Yet before I quit this subject of the extension of the habitable earth, let me remind the reader of the Coral islands; of that separate provision for the same great Final Cause, to which we know not where to place a limit, and which may yet double the present habitable surface, should it be thought necessary. Nor is this all. That the Creator possesses unlimited powers, we know; but that which we cannot see or conjecture, is, in Physical reasoning, as if it was not. But we can see that there is a power in His hand which He has used from all times, which He is using now, and with which, whenever He pleases, under no other interference than we daily see, He may, in one short year or month, render fertile a wide extent of of that desolation which shortsightedness has termed hopeless. And who shall say that even this may not be within His plans, seeing what they are, knowing how He effects them? Archimedes asked but for a

fulcrum, that he might move the earth: may a Modern now dare to say,—place the command of Volcanic power in my hand, and I will render the Sahara as fertile as the declivities of the Atlas.

As the high antiquity of the globe has been demonstrated in the last chapter, from geological evidences, so has a long period of time been assigned to the present earth; to that condition which has succeeded to the last great revolutions. This is argued from the tardiness of the actions of rivers, and from the magnitude of the effects attributed to them. Geologists have endeavoured to compute that antiquity by various means, often by very childish "chronometers," when deposits of peat and accumulations of stalactites, have been adduced as measures of time. Thus also by measuring the annual depth of earth deposited in the valley of Egypt, it has been attempted to fix the period at which the Nile began to flow. But this is equally vain; since the multitude of modifying causes must render all such deposits useless, even as the means of an approximation, independently of the fact that all are not the produce of rivers. Nor need I state the difficulty of making such an approximation from the fresh water formations; while it must always be recollected that no conclusions of this nature need interfere with the historical period of the Creation of man, since this event is totally independent of the geological history of even the present earth.

In treating of the preceding subjects, it became impossible to avoid those questions on which no one can enter, without a deep sense of their grave and serious nature. So implicated is geology in the history of Creation, that those higher investigations, which can alone confer on it that dignity from which it has unjustly been excluded, must otherwise have been abandoned. Nor could it have been avoided for other reasons: since the ignorant at-

tacks on a science so truly pure of all possible offence to religion, demand that answer which is as simple as it is satisfactory; even though its cultivators should despise the united malignity, ignorance, and presumption, by which they have been assailed to this hour.

The time when a correct view of the system of the universe was deemed an act of impiety ought to be past. No one now fears to declare his belief in that which it was left for the most pious of philosophers to prove; and geology demands no other liberty than astronomy. "These are things," says Burnet "which sat uneasy upon the spirits of even the best men who took time to think; but in things," to pursue the words of the same writer, "which are no ingredients of our faith, it is free to differ from one another in our opinions and sentiments." The Sacred Writings form a connected system, the evident design of which is the promulgation of a true religion, and the moral regulation of mankind. If, most necessarily, as regards the Christian dispensation, they trace backwards to the origin of man himself, that origin was not delivered to us as a standard and rule of science. In no place has it been the object of Scripture to reveal the principles of natural philosophy; and if none but a Hutchinson can suppose that its expressions were meant to restrain us on those subjects, with great injustice has any part of nature been selected for this exclusion. The law which compels geology to abide by a standard that was not delivered, is the law that condemned Galileo. If the history of creation was not given as the rule of astronomical science, neither can it have been promulgated as that of geology. That of our globe stands on the same ground as that of the solar system, on the same as that of the universe. No theory can reconcile the rigid words of the narrative with the demonstrations of as-

tronomy, nor can mathematics admit that the diameter of a circle is the third of its circumference: it is no addition to these scriptural difficulties, if injudicious persons will think them such, that its words should prove incapable of being reconciled to the facts of geology.

But it is only for an antiquity prior to the creation of man, that geology asks. From that moment it is reconcileable to the sacred chronology. The Mosaic account is obviously drawn up with reference chiefly to the human race, and there is nothing in the discoveries and inferences of this science inconsistent with it. The cause of truth can never be injured by the pursuit of truth. But it is injured by ignorance, and violence, and persecution: and even the cause of faith suffers in the rash hands of those, who, by overweening zeal, attempt to extend its reign over that, for a rule of which the Scripture was not delivered.

Yet, as there are persons who, from causes much less pardonable than ignorance, or presumption, or vanity, continue to cast the severest of reproaches, not only on this science but on its cultivators, I may fairly enquire whether even the words of that narrative are thus positive and exclusive. They who have attempted a conciliation, by altering the lengths of the periods, have taken an unnecessary, as well as an unwarrantable liberty of interpretation; since they thus wrest the plain words of Scripture to their own evil purposes; too ignorant to perceive the unbounded hazard of such a principle. And it may surprise them to be told, boastful as they have been, that they have not even read, with understanding, the plainest passages of a Book which is more often read than considered, and much too often for the purpose of confirming a religious hypothe- not for discovering the truth.

All that geology requires for the utmost scope of its

great investigations, is comprised in the time which is included in the first and second verses of the history. This is the undefined period with which it is alone concerned; and if the time be truly here indefinite, the difficulty is solved. It was "In the beginning" that "the heavens and the earth" were created; but it is not said that the production of light, and the commencement of order in the vacant and shapeless mass, were simultaneous or immediately consequent. The historian has left the interval between the creation of the universe, and that of light indefinite; as he is silent on what may have occurred: and here science is free to pursue the investigation by its own rules. There might have been many worlds, and animals in those worlds, before the chaotic state described, because that is not excluded by his silence; and this is precisely what geology is capable of proving.

This interpretation is obvious, even in our own translation: it appears still more so in the original. "In the beginning Elohim created the heavens and the earth." This is a completed period, in the sense; and the very term itself seems equally to refer to a period which is not defined. "And the earth was without form, and void." This is a subsequent condition, distinct from the act of creation, the mention of which seems only a general acknowledgement of the Almighty power; and it is that state whence the habitable world is to be made or prepared. And it must be remarked, that in the second chapter, the word prepared, or fitted, is as applicable to the original as the term made; as if implying that the chaotic earth had been adapted, not produced, at that period.

That the original creation, and the subsequent arrangement, were viewed as different by the historian himself, seems also to follow from the expressions used;

confirming the opinion that he is speaking indefinitely in the first verses, and that, in the subsequent account, he has commenced the history of our present earth. The word first used is "Baraa," which means, literally, to create, or to call from non-existence into existence. This verb is again used when man and when whales are created, as this was a real creation; but the term Yaas is applied to other cases. It is another proof that the period of the original creation is intended to be indefinite, when we find the verb "Baraa" used in the absolute past, while all the verbs which follow are in the present or future form; confirming the opinion of the complete separation, in the Historian's mind, of those two periods; and of the creation of the six days as entirely distinct from the original creation of the world. That this was also the opinion of the Translators of the Vulgate seems probable, from the title which they have given; which, after announcing "De opere sex dierum," proceeds to say, "Die enim primo facta est lux;" without noticing the original creation of the earth. They whom I am answering have read as if the heavens and the earth themselves were also created on the first day.

If the verb which is, by some translators, in the seventh verse of the second chapter, rendered "became" instead of "is" or "be," may be thus rendered also where the Tohu and Bohu, the horrible desert and empty state of the earth, are described, it will confirm the same opinion respecting the period first mentioned; by showing that, after the creation of the earth, it is actually said to have *become* an uninhabited chaos; and it will thus sanction, still more strongly, these views respecting the intended meaning of the Sacred Historian, as well as those which geology has here attempted to establish concerning the history of the earth.

PART II.

CHAP. XXIII.

Classification of Rocks.

The more general facts in Geology having thus been examined, under a separation, which, if not perfect, seems all that a System at present admits, I must proceed to the Second Part of this work, or to descriptions of the materials which constitute the accessible earth; though these often entangle enquiries of a general nature. Unfortunately, also, they must often repeat things urged before; because they comprise the Evidences of what has preceded. To produce a System from established materials, is a very simple task: to endeavour to build one out of materials unacknowledged, unknown to others, or controverted, under a perpetual toil through evidences and arguments, is a very different labour: as it is the fate of the writer to pioneer that way which others soon follow; without acknowledgement or effort, yet not without claiming and receiving the praise. But I must premise some remarks on the Classification of these materials; since, besides its practical utility, this constitutes an important branch of Geological Philosophy.

It has indeed been one of the toils of Natural History, universally, to invent or adopt some arrangement of its objects for the purpose of facilitating their study; while if this minor purpose has often been answered by an artificial classification, the philosopher of another ambition has attempted to discover the proceedings of Nature herself, and thus to combine science with utility. Geologists may assume this praise, if they feel entitled to it: but the minuter details of this science are such, and the great relations and analogies so obvious, that without much claim to philosophy, they have followed the right road, though not hitherto with any peculiar success. It is my duty to commence by showing what they have done; since I shall thus, at least, point out what is wanted, though I should leave things little better than I have found them.

Under infinite varieties of aspect, the real and definable differences of rocks are very limited; and hence but few names are required for distinguishing them. In a single mass, also, of one rock, bearing a fixed relation to its associates in nature, the mineralogical characters are subject to variations; whence a still narrower limitation of those names which a superficial consideration might have applied, has been found expedient; by geologists at least of philosophical views. Thus the varieties of granite, of gneiss, and so forth, have been united into mineralogical families, distinguished by a general title. If the terms, genus, and species, have been alternately applied to these, we may neglect this parade of an inapplicable logic, by persons more familiar with words than with their purposes and limitations. But on such a basis may be formed a Mineralogical Classification of Rocks; and arrangements of this nature have been accordingly attempted.

Now it is also found that certain rocks, or families, possess a constant or a prevailing relative position in nature; some one, among many, being the lowest, and some other the highest. If this arrangement were as perfect as has been imagined, there would be a fixed numerical order of succession; or the algebraic notation which has been proposed, under the most unintelligible ignorance of the facts, would serve the purpose of names. I have shown that there is no such order; though there is a prevailing one, of some use in geological science. Further, however, there are certain prevailing associations of rocks; so as, among local or casual differences, to permit of certain general rules: while, lastly, some are always distinguished by a stratified disposition, as others occur in irregular masses. Such facts form the basis for a Geological Classification of rocks; which, comparatively disregarding their mineral characters, attempts to arrange them as integrant parts of the structure of the earth.

Now it is doubtless true, that certain mineral characters prevail, to the exclusion of others, in each of the rocks or families thus distinguished by geological relations; and if these distinctions were steady and perfect, a mineralogical arrangement would suffice for geological purposes: as, reversely, a geological one would serve for those of a mineralogical classification. But, to render such an arrangement unexceptionable, the geological order of nature should itself be constant, which it is not; while the mineralogical classification is not only imperfect, even in its own internal mechanism, but at frequent variance with the geological one, as I have fully shown. It is therefore useless for its own declared objects, and pernicious when adopted for geological purposes. But as a tolerably constant peculiarity of mineral character attends the chief geological divisions of rocks, a geological arrangement,

however imperfect, is not only as valuable as a mineral one for distinguishing these, but is decidedly superior in the investigation of nature. The very basis of geology is the knowledge of rocks; but that knowledge is of little value for any other purposes. If the mere mineralogist desires a mineralogical arrangement of these, he is right; since, to him, rocks are but collections of minerals.

Leaving these to him, therefore, as the philosopher in botany approves a classification of carnations without following it, I must limit myself to those which have been intended to facilitate the study of geology, as declarations of the order of nature, whether truly so or not. A tendency to arrangement, indeed, some love of logic, good or bad, seems to be an inherent propensity in the human mind; but if the sound reasoner adapts his logic to nature, the proceeding is more commonly reversed; while, from the assimilating powers of all systems, an artificial arrangement soon becomes considered as a natural one. Thus, while its inventor learns to see only through his own false medium, his followers cease to enquire, because they believe. I hope to show that the classifications thus esteemed natural, are, on the contrary, artificial. They cannot therefore be received as of the science of geology; it will be another enquiry, how far they are useful in facilitating its study.

Some early but imperfect observations gave rise to the first separation of rocks into two classes; but, while the general principle has been preserved, we can no longer reconcile this simple division to our encreased knowledge. All rocks were thus distinguished into primary and secondary; characterized, respectively, by high, and by low angles of elevation, or, as more decidedly stated, by their vertical and their horizontal

positions. Hence the primitive and secondary classes were established: while other geologists attempted to assign their common boundary; thus rendering this arrangement more useful. Men, believing themselves still wiser, afterwards contrived three classes: making an intermediate one, under the substantive-adjective term *Transition*, and contriving to persuade equivalent minds, even to this hour, that it was a strictly natural arrangement. This classification has also been connected with a system of cosmogony; but it is not worth an enquiry which of the two was the origin of the other. But, if less true than the simple one, as a natural arrangement, and less useful as an artificial one, I must first enquire of the old division into primitive and secondary.

Whatever geographical places the primitive rocks may occupy, they are the lowest in geological position; or, up to their boundary, are inferior to all other accompanying rocks; which thus become the secondary class. It is further stated, that the strata are always elevated at high angles, and that they follow in parallel order, that their nature is chemical, without marks of mechanical origin, and lastly, that they do not contain organic remains. This class, thus determined, is found to comprise certain rocks, under mineral characters, generally peculiar, though not constant: whence arise serious errors in deciding on the geological connexions from the mineral character: as has been common.

The secondary class is, of course, the receptacle of all the rest; and is said to be characterized by prevailing low angles of elevation in the strata, by the mechanical nature of these, and by their containing organic remains; while their order is said to be parallel

to each other, though not to the primitive class. Thus the mutual boundary is placed where the change of order occurs; or the reverse position of two approximate strata, indicates that the lowest is the last or uppermost of the primitive, as the other is the first, or lowermost of the secondary class. If this reverse position should not exist, the boundary is then determined by mineral characters; a conglomerate or sandstone being also the lowest secondary rock, wherever the series is complete: while, if that should be absent, some stratum known to lie above the conglomerate, determines the boundary in question. Such is a view of this arrangement; giving it all the advantages of modern improvements. Its truth and value will be examined, after Mr. Werner's improvement has been stated.

In this, the division is into Primitive, *Transition*, and *Flœtz*; while *Secondary* may be substituted for the last term. The transition class, which alone requires notice, is supposed to be distinguished from the primitive, by containing rocks of a nature partly mechanical and partly chemical; and further, by the presence of organic remains: as, hypothetically, it has a presumed difference of origin, with which we have at present no concern, further, than as thus occupying an intermediate place between the primitive and secondary, it is said to have been formed at an intermediate mysterious period. It ought to be natural, as it is asserted to be so; or if artificial, useful; if it is neither the one nor the other, it also involves objections distinct from those which apply alike to both the systems.

It is not natural, mineralogically, even in the primitive class. Micaceous schist, quartz rock, lime-

stone, and argillaceous schist, sometimes contain fragments or conglomerates, and are therefore partly of mechanical origin, so that there is a fundamental error at the outset; while in the *Transition* rocks, there are limestones, greenstones, and basalts, of a purely chemical nature; so that this asserted distinction has no existence. Organic remains are also rare in the *Transition* rocks; so that the character is further defective: whence it is plain that there are no mineralogical characters, either single or combined, by which they can be distinguished from the primitive. Nor is there any geological boundary by which they are separated from this. None has ever been assigned; while it is evident, that whatever boundary may be assumed, it must be removed, as often as an organic fossil or an imbedded fragment shall occur in a rock, inferior to that last fixed on as its lowest member. Some authors cause it to include the primary conchiferous strata of limestone and schist, for the evident purpose of excluding organic fossils from the primary class; while, with others, it means the lowest secondary strata, or any thing else which they do not chance to understand. And when a recent writer on the Pyrenees says, that the transition rocks alternate there with primary micaceous schist, we can only wonder what new meaning this word is now to possess. Lastly, the absence of the transition rocks, when the primitive and secondary are present, is contradictory to the hypothesis. This class, therefore, as a natural division, is a nonentity; since it is not always present, does not form a transition, has no permanent or certain character, and has no assignable boundary. If there are two or more real divisions in the primary class, under the views of revolutions formerly held out, it is certain that we cannot yet discover them; as,

assuredly, these views had never entered the mind of this inventor of "Transition."

As an artificial arrangement, it neither facilitates the examination nor the classification of rocks: leading, on the contrary, to a vicious reasoning in a circle: certain rocks being first called "transition," and then used to determine the "transition" class: while, its members never having been defined and limited, it serves any purpose that any one may choose. In the other classes, we can always prevent any abuse of this nature by recurring to their geological positions, which are almost always very decided. But that which seems to be the real history of this invention is, perhaps, the best answer to it. As I have shown, under argillaceous schist, its contriver had mistaken the upper red sandstone for the lower; and hence the inferior secondary strata became members of his transition class; while proceeding to assume the presence of organic remains, and of fragments, as a criterion, some members of the primary also fell into it, with the effect of confounding these two real classes, in addition to all the objections already stated. The confusion which it has thus introduced into geological writings is so great as to render many of them unintelligible; since scarcely any thing but a re-examination of the rocks described, can enable us to translate them into a meaning. It is indeed fruitless to seek knowledge in the works of those who use names instead of descriptions; and he who values his time and patience will avoid all those where the term *transition* occupies a prominent place.

In now examining the faults of the antient binary division, the first is the confounding of granite and trap with the stratified rocks. With respect to the asserted characters of these, it is not true that, in the pri-

mitive class, they are necessarily placed at high angles, and, in the secondary, at low ones, or horizontally. In both, they are found at every possible angle; and I trust that I need not quote evidences, when horizontal gneiss and vertical chalk must be known to every geologist, in addition to thousands of cases more. Again, when it is said that a consecutive order, or common parallelism, exists in each class, this, which may be true of the primitive, is not so of the secondary, as I have fully shown; while I need not recur either to the facts or the theory, in this case, which prove that such a secondary class is not a natural one. The whole arrangement therefore is artificial; though, if the main defects lie in the secondary class, as far as the strata are concerned, it evidently confounds, in both, every thing respecting the unstratified rocks, which, in reality, it had not distinguished: while its modern followers either forget this most important circumstance, or persist in preferring a geological Pope to all evidence. But, even as artificial, it is defective by not distinguishing these, and further, by forgetting the tertiary deposits; not to mention also the alluvial and the volcanic substances. It remains to attempt a new classification; while this criticism, demanded by the state of the science and of the practice, will also have tended to explain the grounds on which it is recommended. The emendation of this antient division, which I adopted in the Classification of rocks, did nothing more than separate the unstratified ones; while I even adopted appendices for what I did not then choose to touch. Proposing, now, that still imperfect one, which is all that I know how to invent at present, I must premise a few remarks.

I need not repeat that a Natural classification is the only worthy object of pursuit, while it is, unfortu-

nately, of most difficult attainment. The true philosophical basis consists in Time: it must be sought in the order of the successive productions which constitute the visible earth; and here, within the range of stratification, there is no difficulty. As far as the strata are concerned, Nature has given us the classification, herself: when we see these, we also see their relative dates. Were there only stratified rocks, nothing would be required but what follows; and in spite of all the difficulties arising from the unstratified ones, it is still the basis of a natural classification. A body of strata, consecutive and parallel, is a class: and to find the number of classes, it is only necessary to ascertain each point where a new parallelism, uncoincident with the preceding, occurs. The reasons why each of these is a natural class, have formerly appeared; and it has also been shown that peculiar appearances occur, in any one later class, at the point of each change; consisting chiefly in the presence of conglomerates. And thus have three classes been produced out of the secondary one of the old division; following the same principles, but under more accurate observations.

But Geology now knows what it once did not, that there are rocks every where interposed among the stratified ones, and, moreover, lying below, and also above the whole, which are the produce of fusion and intrusion, not of aqueous deposition. Thus their places among these are not the criteria of their dates; and hence some other mode of classing them must be adopted. That they are of different dates, is indeed certain; but it is neither possible to discover what these are, absolutely, nor to assign, with sufficient constancy and certainty, their relations in date to the stratified ones; in which, the mere fact of relative

position is evidence. Thus does Time cease to be the basis of classification for these; or, at least, if adopted, it can only be under very lax inferences and great chance of error, or under some conventional circumstances. I need scarcely say, that position alone proves nothing, when the very same unstratified rock is proved, as well by facts as by its theory and nature, to be, at the same time, below the lowest and above the highest stratum, in every class, and also in contact with every member in all of them.

Whatever Geologists might have known or thought of these unstratified rocks, they have never yet seen the extent of this difficulty as I have here pointed it out. Though they might have believed granite the produce of fusion, they had convinced themselves that it must always be a primary rock in time, and therefore referable to the primary class, as they thus judged also of certain porphyries, and as, with equal calmness, they assigned all the trap rocks to the secondary. I have shown the fallacy of all this: and thus have I,—yet not I, but Nature,—encreased the difficulty of separating the unstratified rocks into divisions which shall truly rank with the several classes of stratified ones. And hence must we forfeit all hopes of a truly natural arrangement as to these, if Time at least is to be the basis, while I do not now see what other can be adopted. Therefore, in making granite, porphyry, and trap, conventional distinctions, as I have done, I have also classed the unstratified ones as primary and secondary, under the best evidence which can be procured respecting their relative dates. In the former, it has been that they do not, whether really or conventionally, interfere as veins with any secondary strata; while the latter may obviously thus

interfere with the primary, though of the most recent date and connexions. Nor do I see any other expedient, except that of making a single class out of all the unstratified rocks; while I think that Geologists are not yet ready for such innovations.

This is the great obstacle to a truly natural classification; some minor apparent blemishes, yet rather, practical ones than aught else, are soon described. Such are the repetitions of the same rocks in more classes than one. Custom has tolerated this separation in the limestones and others, and justly enough, as a question of time: so that, following it, I have done the same as to serpentine, and as to the rocks modified by heat, namely, the siliceous schists, cherts, and jaspers. The recurrence of the very same rocks in different classes of the " secondary" strata, and also in the tertiary, even indeed in the alluvia, as in travertino, are practical or mineralogical blemishes of the same nature; but if the classification is to be geological, and for the purposes of geological science, this must be; while the mineralogist may make his own distinctions; Geology merely entreating, that he do not attempt to write about it on such a basis, and requesting the philosopher in names and specimens to confine his genius to his own drawers, the logic of which, like his own, is not that of Nature.

Though there may be no prospect therefore of producing an unexceptionable classification, either natural or artificial, especially under the double and often contending claims of Mineralogy and Geology, I am bound to make the attempt: while, really, the other branches of Natural History must recollect that their own success has not been very splendid, and, that among the natural sciences, this most recent of all is almost

triumphant, compared with even the last and most fashionable arrangements of Zoology. Imperfect as any arrangement may be, its uses are still apparent; and were it no more, it might stand, like a Code in Legislation, as a beacon to direct what time and knowledge may hereafter demand. If I am not satisfied with the following attempt, I have caused it to coincide with the antient binary one, so as to allow of its use as a mere improvement of that; and if I have only numbered the new classes, merely suggesting an ordinal Greek term to those who love Greek just as they least understand it, it is, that to make names before we are sure of the things, is not the most prudent policy.

A few further remarks on this table will complete what the reader might not observe for himself. I have already given reasons for repeating the same rocks in more classes than one, and for distinguishing the porphyries and traps into at least two classes. In the fifth class, I have only given the principal varieties: a fuller list, derived from the English strata, would be topographical; while did I distinguish minutely in the later rocks, I must have adopted the same proceeding as to the endless varieties of gneiss and others in the primary class. The strata thus named are not given as if in the order of nature, because I have already shown that there is no such order: and, in the secondary class, the order of England, if that be expected, is but an order among varieties. If I would gladly have extended the few minute commentaries given in the table, it was incompatible with that form. I have only to add, that if my plan does not allow me to follow it in the subsequent descriptions of rocks, so have I been obliged to refer, for their details, to that work on their Classification which is the grammar of the present one, and of the science.

Artificial System.	Natural System.
PRIMARY CLASS.	Class 1.
STRATIFIED.	Protolith ? &c.
Gneiss.	
† Micaceous schist.	
Chlorite schist.	
Talcose schist. partial.	
Hornblende schist.	
Actinolite schist. partial.	
* Quartz rock	
* Red sandstone	
† Argillaceous schist. fine clay slate and gray-wacke.	
Diallage rock. Apparently ambiguous.	
Serpentine. Ambiguous.	
‡ Limestone.	
Compact felspar. Partial.	
Jasper, modified from * / Siliceous schist, modified from † / Chert, modified from ‡ when argillaceous — where granite or trap are present: partial.	
UNSTRATIFIED.	Class 2.
Granite. From the ordinary appearance, to that of greenstone and basalt.	
C. Felspar porphyry. When decidedly limited to the primary strata / Clinkstone and Claystone. In the same cases. — often doubtful	
Serpentine. When solely connected with primary strata, or granite.	
Diallage rock. Not satisfactorily proved.	
SECONDARY CLASS.	Class 3.
STRATIFIED.	
Series below Coal: * Sandstone. Conglomerate and fine. Old red. Of various colours and qualities.	
Series below Coal: Limestone. Mountain limestone of English. *Transition* of some.	
Coal series: * Sandstone. Various.	Class 4.
Coal series: † Shale } Do.	
Coal series: * Clay } Do.	
Coal series: Limestone	
Coal series: Coal	

Artificial System.			Natural System.
	Limestone.		Class 5.
	Magnesian. First above the coal series		
	‡ Argillaceous. Lias, Muschelkalk, &c.	with lignite coal	
	Compact. Various; generally organic	with lignite coal	
	Oolithic.	with lignite coal	
	Chalk.		
	* Sandstone		
Series up to Chalk or marine clay.	Red marl. Red sandstone containing salt and gypsum		
Series up to Chalk or marine clay.	White. Various, and sand. Quadersandstein, &c.		
	Ferruginous, and sand	with lignite coal.	
	Green, and sand.	with lignite coal.	
	† Shale	various	
	* Clay	various	
	Jasper, modified from *	partial: only where trap rocks are present.	
	Siliceous schist, modified from †	partial: only where trap rocks are present.	
	Chert, modified from ‡	partial: only where trap rocks are present.	
	Salt and Gypsum considered as minerals in this class.		
UNSTRATIFIED.			Class 6.
	Serpentine. As connected with Trap chiefly.		
	Diallage rock.		
	Pitchstone. Comprising pearlstone. Known only in veins.		
	Trap.		
	Indurated clay. Base of the amygdaloids.		
	Claystone.		
	Indurated claystone. Comprising some so called basalts.		
	Clinkstone.		
Overlying and venous rocks referable in time to Class 3, 4, 5.	Compact felspar.		
Overlying and venous rocks referable in time to Class 3, 4, 5.	Basalt. Of hornblende only.		
Overlying and venous rocks referable in time to Class 3, 4, 5.	Greenstone.		
	Syenite. Sometimes emulating granite.		
	Augit rock.		
	Hypersthene rock.		
	Porphyries. With various bases.		
	Amygdaloids.		
	Tuff. Of eruption, only or chiefly.		

Artificial System.	Natural System.
TERTIARY CLASS. Lacustral: marine, or fresh water; or Æstuaries, elevated. { Limestone Sandstone Chert. Millstone Shale Clay Marl Gypsum } All fresh water or all marine: or uncertain successions of marine and fresh water strata. With organic lignites.	Class 7.
ALLUVIAL CLASS. Marine. Antient, Elevated: indurated, Marl of Italy, &c. —— —— loose. Italy, with marine remains. Elsewhere? Of the present ocean, under protrusion and retirement, or elevation: false and presumed tertiary strata, with woody lignites. Coral: Islands of Pacific, &c. elevated or not.	Class 8.
Terrestrial. Loose: of various materials. General: under antient elevations and currents } with woody lignites. Local: from fluviatile transportation } with woody lignites. —— from local disintegration; at rest, or moved. Soil. From do. and transportation through rains. Sand. From winds. —— Solid. Travertino; of Italy, &c. Coral sandstones. Marine and terrestrial together. West Indies, &c. Rocky strata, as in Chap. 7, of lakes drained or filled, not elevated. Marl of lakes. Terrestrial marl. On dry calcareous surfaces. Peat. With submerged wood.	Class 9.
VOLCANIC CLASS. Lava Scoria Pumice Tufa. } With resemblances to porphyry, amygdaloid, basalt, &c. in the trap rocks.	Class 10.

CHAP. XXIV.

Granite.

If the remarks on the unstratified rocks have anticipated much of the history of Granite, their effect has also been to produce repetitions, not limited to this rock alone, yet inseparable from the plan of this work, without a sacrifice of utility to literary neatness. The term Granite is so current, and the substance so familiar, that it seems superfluous to define it. Yet there is no rock respecting which geologists have more misunderstood each other. Nature has thrown considerable obscurity into the subject, and they have, too often, so managed as to increase it. This confusion has arisen chiefly from viewing it as defined and distinguished by nature; whereas, if considered as a genus or family, it must be on artificial or conventional grounds, unless we are to go on in darkness and disputation for ever.

The term Granite has, by some, been limited to a compound of quartz, felspar, and mica, and the word Syenite adopted for those containing hornblende; laying the foundation of a large progeny of errors. The distinction is as unfounded as it is pernicious. To the first compound there is sometimes superadded hornblende, or else it becomes a substitute for the mica, producing a granite even more abundant than the first; while the ternary compounds also lose one or other of their ingredients, and become binary; all these varieties further occurring in the same mass, and often within a very small space. In Nature, therefore, Granite ranges within four essential minerals, quartz, felspar, mica, and hornblende, in dif-

ferent combinations, of two, three, or four. If this were merely a question of mineralogy, the distinctions thus condemned might be conceded without inconvenience. But as the nomenclature of rocks is a nomenclature for the purposes of Geology, it is easy to see what fallacies may intrude from an improper use of terms: as has happened from that of Syenite, thus making a distinct geological rock of any granite which happens to contain hornblende. Thus have the latest been confounded with the older unstratified rocks; not only producing inextricable confusion, but permitting trifling observers to impose on their readers by false or flimsy statements founded on mere terms.

The minerals of granite, both essential and accidental, are united by a confused crystallization; the endless variety of proportions, sizes, and colours, in the ingredients, producing corresponding differences of aspect and of texture; while many different textures often unite in one mass. Though, in general, uniformly granular, the felspar is sometimes separately crystallized, so as to form "porphyritic" granite; as is the case much more rarely with the quartz and the mica. Occasionally, it splits in one direction preferably to another, though the ingredients are still uniformly confused; there being a slight tendency to the parallel position, as in gneiss, while when this is not visible in the mica, an acute eye will discover that the felspar has crystallized under a common polarity, so as to produce this effect.

Did the mineral history of granite terminate here, its character would be sufficiently defined; and we should not be compelled to adopt a conventional one in distinguishing it for the purposes of Geology. But, as formerly shown, its mineral characters are often

undistinguishable from those of the most common trap rocks; as, on the other hand, examples sometimes occur in these, resembling the ordinary granites: while, in these cases, the granite of mica, quartz, and felspar, passes into the variety containing hornblende, then into a compound of hornblende and felspar, or the greenstone of the trap family, and lastly into similar ones so minute in texture, as to be absolute specimens of basalt and claystone. And reversely, a claystone in the trap family graduates into a granite of the four usual ingredients; resembling that which is inferior to the primary strata, though it is superior to the secondary. Now as these two families are far distant in time and connexions, and as this forms, in fact, their leading geological characters, we must either discover some mode of always distinguishing them by natural marks, or establish some artificial rule, for the purposes of geology: though, in a rigidly philosophical view, having a common origin, and being, thus, fundamentally, the same. If, in most cases, the mineral character coincides with the geological one, mineralogical granites occurring in the lowest positions, as mineralogical traps do in the highest, this distinction is inapplicable to the cases in question. Either, then, we must unite the whole under one term, or distinguish the two, in every case, by their mineral characters, or, lastly, define them exclusively by their geological positions.

Under the first of these systems, the result will be an obvious confusion in geological descriptions, unless we adopt a mode of proceeding for which the science is not prepared, however it may admit of that hereafter. If the distinction be made purely mineralogical, it will become impossible to know, whether the terms "trap," and "granite," are always applied, respectively,

to rocks later than the secondary strata, and to rocks beneath the primary. If, lastly, we adopt the distinction founded on geological position alone, the term granite will always mean the lowest rock in nature, we shall continue to understand Geologists in what is most essential, namely, its geological position; and our own descriptions will be subject to no misapprehensions in this essential point, while the specification of its mineral characters will remove all chance of error. I have therefore chosen this plan. Mineralogists may still arrange their specimens according to their own rules; but Geologists must learn to understand each other, on those points which constitute their pursuit.

I may here extend this remark, since the recent increase of a serious abuse seems to demand it. If a steady mineralogical composition was attached to certain geological characters in rocks, mineralogical terms would, not only be admissible, but desirable. But as this is not the fact, the one cannot be a substitute for the other, while it becomes a source of inextricable confusion, cheating us with words. Geological descriptions, formed on such a nomenclature, are the work of those who know nature only in their cabinets, and who should confine themselves to the histories of their specimens. It is their least offensive quality to be useless; they are too often the sources of pernicious misrepresentations, or the fallacious and imaginary evidences of false theories, as of false descriptions. It would be invidious to point out the mass of writings thus rendered worthless or mischievous; or to name that nation to which we are chiefly indebted for a barbarous neology, which has incalculably augmented these evils.

Whatever facilities this definition may appear to

give, there are, nevertheless, cases where we may still be at a loss which term to apply justly to a particular mass, as there are others where one superior to the secondary strata may really be a granite. If a rock, with the mineralogical characters of granite, in this position, should be connected with one of similar, or even of other characters, inferior to the primary strata, it must be considered as a granite, because its character is decided by this portion. If a granitic rock be connected, on the contrary, with a mass having the geological position and mineral characters of trap, as is the case in Sky, it would be pronounced a trap rock. Should it, lastly, betray neither connexion, we shall still pronounce it a trap, from its position, though it may actually possess connexions with an inferior granitic mass which is invisible or inaccessible, and be thus a real granite. In a reverse manner, should there occur a mass having that deep connexion which all unstratified rocks must possess, and of which the portions superincumbent on the secondary strata had disappeared, while the rest remained, it is evident that it must be ranked with granite, according to the adopted rule. This would be the decision of every one, were its mineral characters granitic; though it might actually be of later date than the latest strata, and still, perhaps, preserving some connexions, to prove its true nature. If its mineral characters were those of a trap rock, if it were even a basalt, I have shown that it may still be connected with true granite, and fairly entitled to that name. Thus, even under this definition, we may decide wrong respecting the real nature of some given instance of these rocks, because their origin is really the same: and hence, whatever prevailing distinctions there may be, both in their mineralogical characters and their positions, the only real ones are

the dates of their production; while, from the peculiar circumstances under which they occur, we cannot always distinguish those relative æras.

Such are the consequences arising from the very nature of these rocks; and one of the results must be obvious. The distinction, which appeared to be natural, proves to be artificial; or it is conventionally agreed, that all rocks of a certain character, are to be granite when in one position, and trap when in another. It is therefore useless to ask whether granite can be found lying over the secondary strata, unless where a communication with an inferior mass is discovered; since, by the very definition, it is placed in the trap family, while that definition proves, in itself, to be a postulate. I must here further remark, that these conclusions, into which those who define granite by its mineral character, and those who define it by its inferiority, are equally forced, are independent of an igneous, or of any theory. They are mere deductions from acknowledged facts, which ought to have been made long ago, and which, if they had, would have saved much obscurity and controversy. If the lowest unstratified rock in nature had always been a mixture of quartz, felspar and mica, and the highest a basalt or a claystone, the antient method of geologizing on this point might have answered all purposes; while this imaginary law has led to all the past confusion, since it was sufficient to find a specimen and apply a name, when all the rest followed of course. But it is fully time to abandon this method of philosophizing; and, regardless of names, to see what the things themselves really are, and what are their connexions and analogies in nature. If I have dwelt on this most practical and important, not speculative matter, it is not merely because it has been unseen and

unthought of by all geologists: but, because so much of the history of both granite and trap depends on it. I need only repeat, that in what follows, granite is considered as a conventional rock, determined by inferiority of position.

Notwithstanding this inferiority, we must not grant, as asserted, that granite constitutes the mass of the globe, or is the lowest rock in existence. Of its interior, we know nothing; but its weight is sufficient to prove that it is not formed of granite. Respecting the other assertion, there is neither experience nor reason in favour of it. Some unstratified matter, solid or fluid, does doubtless lie beneath the stratified surface of the earth; but while conjectures are fruitless, it might, if solid, be basalt, as well as granite. But, omitting all speculation, the volcanic rocks of Auvergne have flowed from beneath, through granite, and contain a large proportion of iron, while that rock contains very little. Hence, it is not there the lowest substance.

The same persons have also considered it the first rock that was formed. Though treating of it first in order, it is plain that it is not so viewed here; while I need not re-discuss the relations of the stratified to the unstratified rocks. It is sufficient that granite disturbs the former, transmits veins through them, and affects their mineral characters; while the strata do not follow it in that regular order in which they succeed each other, but are variously and confusedly placed with regard to it, so that a single mass may touch all the members of one series; a property not possessed by any stratum. This is posteriority; but it is a posteriority only where the fact of intrusion is thus proved. Rocks have been deposited on it, as I shall immediately show; and in examining the revolutions of *the Earth,* I have rendered it pro-

bable that there has been granite, or an analogous substance, prior to all strata, and the original source of the whole. That very granite may be visible; but we cannot as yet distinguish it from the many successive ones which have acted in the elevations of the strata.

With its mineralogical resemblance to the trap family, there are many striking points of correspondence in their geological disposition, and in their relations to the secondary rocks. But I need not re-examine a subject formerly discussed under a general view: though some of the particulars will re-appear in this and the succeeding chapter. But as granite has been said to be distinguishable under certain æras of formation, leading to the terms of primary and secondary, of older and of newer, I must enquire of that matter. The ordinary criterion of such ages, thus produced, is fallacious; though it has certainly been formed at many different periods. Among stratified rocks, the criterion of superiority will, in general, mark the latest. But between an unstratified intruding rock, and a stratified one, there can be no such assignable relation; since the former may be equally in contact with the strata of various ages, if it be posterior to the whole. Though it should be posterior to some only in a series, we cannot even then know the relative period of its formation; as it might not have come into contact with every stratum of the mass into which it has intruded, even though of later origin than the whole. There is no criterion then of this nature; but there is one by which the relative æras, at least, of two masses of granite can be determined. That is the passage of veins from one mass into another: a fact, of which the value has, from hypothetical views, been generally overlooked. The

same hypotheses make it important to remark, that in Shetland, where there occurs a red micaceous granite, together with one containing hornblende, and passing into basalt, the latter is the oldest, since it is penetrated by veins of the former. This fact proves the antiquity of those granites which, from their resemblance to trap, might be esteemed comparatively modern: and also, that the mineral composition is no test of antiquity, as has been said. The latest granite here, is that termed "genuine old granite" by the Germanic teachers of what they did not know. Whatever therefore may be the fact, we cannot at present determine the age of any granite, except where this occurrence takes place; since the supposed proofs from mineral composition are worthless: whence the term *genuine* granite is only admissible as a distinction for mineralogists.

Granite is one of the most universal rocks, forming some of the highest and most remarkable chains of mountains; being thus the most elevated, in absolute position, as it is supposed to be the lowest in a geological one. It is not however limited to such high chains as the Himálya or the Alps, or even to the much lower ridges of Britain; since it also occupies many extensive tracts of comparatively level land. Hence it presents that diversity of picturesque outline formerly noticed; and if this variety sometimes results from disintegration, the same effects arise from its natural disposition. In these cases, it forms tracts of various extent, though often constituting single mountains, or groups, or ridges, far separated from any analogous mass; as it sometimes also occupies places so small as not to be easily discovered. That difficulty is much increased where it is surrounded by gneiss, as in Scotland, where such insulated masses frequently

occur, not exceeding a few yards in extent. In such cases, it is probably the protuberant summit of a larger mass beneath the surface; while in favourable situations, such a portion may gradually increase in extent, from the degradation of the softer strata above it.

It was already observed that granite might be in contact with any rock of the primary series; and, in this case, its relative date to any member is proved by the passage of veins through that stratum. If these had been deposited by stratification upon it, the same contact of all the members might exist; but there would be no intruding veins or disturbing masses. For the same reason, even the secondary strata may repose on granite without intervention of the primary; because it was not every where covered by these when the former were deposited. In this case, the masses or veins could not interfere with the strata; and, should that ever occur, such a mass of granite must be posterior even to the secondary deposits.

The contact of gneiss with granite, once supposed indispensable, is so frequent, that instances need not be quoted; while there is often such a transition at the place of meeting, both in general forms and in the mineral structure, that the boundary is imperceptible. In this connexion, the intrusion of veins is a frequent feature. It is found in contact with micaceous schist in several parts of Scotland, occasionally sending veins into it; while, as quartz rock occurs in the same situations, it is equally found in contact with that substance, and equally transmitting veins into it, as in different parts of Aberdeenshire and Perthshire. Glen Tilt and Shetland present examples of its intrusion into primary limestone. In Aberdeenshire, serpentine is often in contact with granite, as noticed in the history of that rock. Its contact with argillaceous schist

is so common, that I need only quote the examples of Cornwall and the South of Scotland; and the passage of veins through the schist is equally well known. I need not notice the other primary strata, since, as far as their geological relations are concerned, they are all implied in those now enumerated; but it is apparent that granite is, or may be, posterior to the whole mass of the primary series, as it is, somewhere or other, more recent than every member of it.

The only instances known to me of the contact of granite with the secondary strata, are those which I have discovered in Scotland, elsewhere noticed. In Caithness and Sutherland, the lowest red sandstone in one place, and the series of the lias and oolithe with coal in another, reposes on the same mass, so that every member in a very extensive deposit, is in contact with a granite, which in other places, is in similar contact with gneiss, quartz rock, and micaceous schist. Thus the possible proximity of granite to every secondary stratum is proved; since there is no reason why it should not extend higher up in the whole series. There are here however no marks of intrusion: so that these strata have been deposited on the granite and its accompanying primary strata, at the same period. Yet this fact proves the antiquity of the granite in question: since it must be more antient than that which elevated the primary and secondary strata together, and which seems never to have intruded among the latter, unless it has done this under the form of trap, so utterly incapable of disentanglement from granite in these cases.

If I have rejected the case of granite reposing on the secondary strata, referring it to the Trap family, by the definition, yet as others may choose to consider the mineral character as constituting granite, in what-

ever position, I must mention these instances; though, for want of correct views, the observations which I shall quote from authors are of little value.

In Sky, where I first described this fact, it forms a considerable mountain, the subjacent strata belonging to the lias limestone: while it is an unquestionable member of the trap family; because it is connected with rocks, which, in some place or other, contain every member of it that has been described. In confirmation of this fact, Mazzari is quoted by Breislak, for granite lying, not only on secondary (Jura) limestone, but on the marine alluvia of Italy, formerly mentioned. But this requires some explanation; because even trap has not yet occurred of so modern a date, in any part of the world. It might be wrong to suggest that this is a volcanic rock; a volcanic granite; yet if rightly examined it can be nothing else. Had it even been thus deposited on these alluvia while under the water, it is but a submarine lava; though it is evident that this is the precise case in which lava and trap become the same thing. Whatever may be the fact, however, as to this part of the observation, it is admitted by others who have examined the spot near Predazzo, that this granite does lie above the Jura limestone; while it is no less important to know that it presents numerous varieties, and passes into porphyry and augitic greenstone. At the same time, the strata in contact, consisting of the red marl, or variegated sandstone, the muschelcalk, and the oolithe and lias, are in some places, modified, and, in others, formed into breccias by the consequences of its intrusion. Granite has also been found by Von Buch in Norway, lying on secondary limestone; as confirmed by Haussman. Being described as connected with porphyry, it is probably analogous to that of Sky.

Similar occurrences are described by Raumer and De Bonnard, in the Hartz and near Dresden; as "Syenites" in the same position are also mentioned by Brongniart, Omalius de Halloy and Engelhardt. As far as the sight of the specimens can determine any thing, I should refer these to Granite: they may be members of the trap family; but observations which consist of names or specimens only, are useless for the purposes of geological reasoning. Brongniart's nomenclature disregards all geological relations.

If no opinion, therefore, can be formed, of these last, except by those who are satisfied with mineral characters and names, we have still to find a case where a mass of granite, beneath the primary strata, is connected with another lying above the secondary. This case alone could satisfy all the conditions; since it would be admitted as an overlying granite by all parties. The consequences however, must obviously be, to prove, what I formerly suggested, that the origin of trap and granite are the same, and that hence all their mineral and geological characters correspond so nearly.

Granite is, perhaps most commonly, found in huge masses, void of all configuration, and even of a tendency to one, though in other cases it presents peculiar structures. But no instance of stratification has been produced, notwithstanding the repeated assertions of this nature; nor can it exist, consistently with the meaning of that term. It is true that beds of gneiss cannot sometimes be distinguished from granite; but these are only extreme cases of a stratum which, in granitic gneiss, frequently approaches to the character of granite. Aberdeeenshire presents striking examples of this fact, while there is often a perfect transition between the two. The instances of stratification commonly adduced, are, however, examples of

the laminar disposition sufficiently common in this rock. This presents a considerable analogy to the similar forms in the porphyries; the laminæ being exceedingly variable in extent, but rarely very continuous without interruption, as strata are, but commonly of different thickness in different parts; or irregularly extenuated and encreased. Nor are they prolonged according to the dips or bearings of the surrounding strata, which, under certain variations, always preserve some general tendency. On the contrary, they are always irregularly placed, even when in immediate contact with these, so as to occupy every possible position within a very limited space. In such beds the straight passes into the curved form, or, finally, into a large spheroidal structure. The prismatic form is sometimes also combined with the laminar, as in the porphyries; to which, in all else, granite presents a strong analogy. The thickness of the laminæ is various; sometimes descending to a structure which has been improperly called schistose. Hypersthene rock, which is an unstratified Trap, presents equally all these features; and hence, in each case, they must be considered as modifications of a concretionary structure. The magnitude of the objects is a circumstance of no account in the extended operations of Nature: nor need I do more than remind the reader of the pinnacles of the Alps, where observers, who should have known better, have imagined an erected stratification.

Granite beds sometimes present other forms, by which this rock is recognized, even at a distance; though they occur also in the older sandstone. These, the short prismatic and cuboidal, are, however, partly the result of an incipient decomposition. The beds are originally intersected by fissures, often at right angles, which under exposure to air and water, enlarge,

until, at length, the masses become separated, as if they had never been connected. Thus they acquire the appearance of piles of masonry, often putting on strange forms, like the Cheese-wring in Cornwall, and producing the well-known rocking stones. Under a further decomposition at the angles, these masses become a heap of irregular spheroids, which, being often easily removed, roll down the declivities of the hills, forming some of the travelled blocks so often discussed.

Among these indications of a peculiar internal structure, I have formerly described the exfoliations into spheroidal crusts and schistose laminæ, so as to render any further notice of them unnecessary. Decided marks of concretionary arrangement are also found in the occasional orbicular tendency of the component parts; familiar in the well known variety of Corsica, and in "Tiger granite," and sometimes marked in a circular distribution, affected by the mica in ordinary granite. They all present analogies to the similar structures occurring in such porphyries as that of Corsica, in the Traps, and in the products of earths fused by artificial heat; and I need not now repeat their bearing on the igneous origin of these rocks.

The last circumstance in the geological character of granite, relates to its distribution in the form of veins; of which there are two distinct kinds. The first lie wholly within the rock, consisting of the same materials, under slight differences in the colour and magnitude of the parts, being also connected with similar variations, of a concretionary appearance, without the venous form. If the exact cause of these is not obvious, they are connected with that venous structure formerly described, which is only detected by the exposure or disintegration of the rock.

The next are much more interesting, and constitute

the principal arguments respecting the posteriority of granite to the strata with which it is associated. These vary infinitely in their dimensions, extent of course, entanglement, and ramifications. At times they are rather protuberances from the general mass, than veins; while at others, they extend to great distances; insinuating themselves widely into the surrounding strata, above all, in gneiss, in which rock also they especially abound. Thus also their thickness varies, from many yards, even to the minuteness of a thread, being simple or ramifying; and often also presenting the most intricate reticulations. In composition, the larger veins at least, sometimes resemble the parent mass, while, in the smaller, the structure often becomes minute, as if proportioned to the magnitude of the vein. But; more commonly, the materials are crystallized on a much larger scale, producing the well-known specimens of felspar and mica: as, in these veins also, the accidental minerals enumerated in the Classification are chiefly found. Yet the size of the ingredients does not bear a proportion to that of the vein; the larger crystallizations as often occurring in the small as the large ones.

It is also not unusual for the mica and the hornblende to disappear in the progress of the smaller veins, while quartz and felspar are always the predominant ingredients: as, further, even the quartz often disappears, so that the ulmitate ramifications consist solely of felspar. And though hornblende is as common an ingredient as mica in gneiss, it rarely occurs in the veins that traverse an example of this variety, though mica is present in those which are found in micaceous gneiss. Occasionally, and even in a large vein, all the crystals of felspar preserve a common polarity, however interrupted by other minerals; so

that the rays of light are reflected from it at the same angle over a wide space, leading to its detection at a distance, as I have also noticed under the head of gneiss. We might, in such a case, imagine the whole vein to be a single crystal, deficient in external form only because there was not a vacuity in which that could have displayed itself.

Though the variety of granite called graphic is not limited to the veins which traverse gneiss, it is most frequent in those, though seldom occupying the whole of one. I need not describe what belongs to the business of mineralogy; only remarking, that it is sometimes the quartz, and at others the felspar, which has first crystallized, and thus determined the figure of the other mineral.

A third kind of granite veins has been mentioned, independent of any central mass. There is no reason to presuppose this; and I have traced to the parent granite all that were pointed out as such in Scotland. Their great size and long persistence seem to have led to the notion that they differed from the veins in gneiss; but while it is evident that no small vein could occupy a great range, they are analogous to the similarly persistent veins of trap, as their connexions must thus be equally difficult to ascertain. That granite veins traverse masses of granite, is a fact that I have used to prove distinct ages in this rock; while they are often marked by the same peculiarities of character as when in gneiss. In those which traverse this substance, the texture is uniform throughout; but in others, it very often differs in the middle and at the sides. Yet they are often so amalgamated with the gneiss that the boundary is undefinable; the mica or hornblende losing their parallel directions,

so that it becomes granitic; from chemical changes which I must shortly proceed to notice.

In the vicinity, as well as at the contact of the veins, the strata are generally broken and diverted from their otherwise even position, while fragments of them are often also found detached and insulated among the intersections; gneiss, in this case, being sometimes so placed and extenuated, as itself, to put on the fallacious appearance of veins. Even the protrusive force of the vein is often indicated in the averted direction of the edges of the strata in contact; while the variety of the appearances marking violence, however demonstrative of the nature of the actions which produced them, need not now be repeated. I must not however omit the formation of conglomerates from the invaded rock, at these poiuts; a circumstance equally occurring, like every other one, at the junctions of Trap.

The chemical changes of the strata at these points are often such, and so extensive, as to have rendered it necessary to enumerate some of the rocks so influenced, under separate titles from those whence they have been thus produced. Gneiss thus becomes converted from the schistose to the granitic character in almost every case; clay slate into siliceous schist very widely and generally, and, into hornblende schist, in a more limited manner, though sometimes very extensively, as in Shetland. The entangled fragments are also often changed into the same substance; while the cause becomes demonstrated by tracing the gradual nature of that change where the continuity is uninterrupted. In the same situations, quartz rock is indurated to a crystalline texture and hardness; and, when containing felspar, it becomes jasper, as in Ben na chie. It is repeating former general state-

ments, to note the peculiar interest of these changes; while they resemble those which take place in the argillaceous sandstones and the shales when in contact with trap. Similarly, the stratified limestones become amorphous; while their texture also undergoes a change from the earthy to the crystalline, when pure, as, when originally impure, they become cherty substances, or else perfect cherts. A change not less remarkable occurs in Glen Tilt, where the limestone in the vicinity of the granite is interleaved with cherty laminæ; while it is easy to see that it has been produced from a bed consisting of alternating laminæ of limestone and schist; the latter having been indurated to its present nature, while the calcareous portion has remained comparatively unchanged. All these remarkable appearances, which I long ago described, abound in Scotland; and they have all been recently confirmed by foreign geologists; the last by Ramond, in the Pyrenees.

If there is little more to remark respecting the Theory of Granite, than what is deducible from this chapter and that on the unstratified rocks, a few points still demand notice, while I presume I can now trust to the reader for combining the whole. Respecting its successive productions, there ought, *a priori* to be a sufficient number to account for the first great revolutions of the earth, and also for that original rock whence the first primary strata were produced. There are at least three traceable through successions of veins; but I shall hereafter show, that *quoad hoc*, the older porphyries and granites are identical, while not essentially differing in composition. Geologists, reasoning as usual, even where they admit the igneous theory of this rock, persist also in imagining that all the visible granites must have been

brought to their present places in a state of fusion, and that every case of contact with the strata must be one of this nature. But the older must have been elevated by the later in a solid state, as the strata have been, whatever changes heat may have induced in them at the contact of the fused mass, as it has in gneiss; so that some of the disputed appearances respecting granite may be explained on this ground. On the often discussed overflowing of granite, I must remark, that the facts here described, and our knowledge of the changes of crystallization which fused rocks undergo in consequence of more or less rapid cooling, prove that an overflowing granite might be a trap in every point of character. Whence the present most important, and new conclusion in geological philosophy, namely, that as agents in the changes of the earth, granite and trap are identical, and that while there is an uninterrupted succession of these, the fact that their characters are interchangeable, even when of one æra or in one mass, shows that geologists have drawn a boundary where there is none, and that they cannot even be sure of any one trap, except under the clear proof of recent intrusion; the only test of date, yet never a negative one. The explanation and general bearing of some minor points are so obvious, that the reader ought to be indignant at seeing them here stated.

Granite presents great variety in its tendency to decomposition and in the rapidity of that process. As formerly noticed, it does not always require exposure to air; since large masses are occasionally found destroyed, deep within the earth. If invariable rules cannot be established, those which contain red felspar are least exposed to this change; from obvious chemical causes; though the mica sometimes produces

this result through the rusting of its iron. The felspar sometimes also appears to suffer this change from the alkali in its composition; thus producing the well-known porcelain clays. Hence the colour of granite is no rule on this subject; many of the pale ones being as durable as the red. But those which contain hornblende in place of mica are the most durable; while this property is most perfect as they approach the nearer to greenstone, combining, then, strength also with durability. This is a question of importance; from the extensive use of this rock in architecture, and the popular notion that granite is necessarily a rock of the highest durability. The works of antient nations are sometimes indebted to climate for their duration; and it must also be recollected, that, under this general term, are comprehended many substances, essentially differing in the proportion, mixture, and nature, of their ingredients.

Considering the resemblance between granite and gneiss, it is remarkable that the latter should so much more powerfully resist decomposition; as is very evident in Scotland at least, almost universally. The soils produced by granite vary according to the nature and proportions of the ingredients, especially of the felspar and mica in the original rock. Where quartz predominates, the soil is necessarily barren.

Metallic veins are found in granite; and, to us, those of Cornwall are the most remarkable, containing principally tin and copper. Lead, arsenic, cobalt, zinc, wolfram, bismuth, silver, and iron, also occur; and to these may be added, if less common, manganese, titanium, uranium, and gold.

CHAP. XXV.

Overlying and Trap Rocks.

THE preceding tabular Classification is a necessary portion of a System of Geology, and a ground of reference for the rocks here described. But, having taken different views of what the science demands, I shall not here follow it: while if geologists have persisted in treating of the later trap rocks after the secondary strata, it has not been from a correct theory, but from following that German arrangement which I have discarded. It is true that there are trap rocks later than even the chalk; but they are also of all ages, and cannot therefore be separated by geological dates without leading to numerous repetitions. Mineralogically, there is no such distinction between the apparently oldest porphyries and the demonstrably newest ones, as to allow us to connect these with their geological ages; while there are some as antient as granite, or older at least than any secondary stratum. If they are therefore to be united in one family of unstratified rocks, as they must be, they follow it as their most fitting place. If, also, after an examination of granite and trap, as new as I believe it to be just, I have succeeded in showing that they cannot be effectually distinguished as mineral compounds, and that their geological distinctions are also evanescent, or unassignable except under a conventional arrangement, the same, even more frequently, is true of the oldest porphyries and the newest traps, here united in one division; while for want of that criterion of ages already shown not to exist in these rocks, except in casual instances, we are often as unable to assign the probable date of an antient porphyry as of a recent

trap. I have pursued miles of a porphyry lying on argillaceous schist, believing it more antient than the secondary strata: yet a single vein intersecting the red sandstone or the coal series, has in a moment reduced this date. Undoubtedly, there are porphyries more antient, ranking with the granites, perhaps of more ages than one. But whatever the apparent proofs may be, we can do nothing unless we could command the negative facts also; and this cannot be. The porphyry of Inverary and that of Kirkcudbright appear of different ages; but there is a secondary rock within reach to betray the date of the latter, while there is not one to tell us what the former might have been.

I would indeed willingly separate the antient "porphyries" from the modern ones and the traps, because of their respective connexions and dates, if I knew how to do it; since it would be convenient, until geologists are willing to receive what I dare not now attempt, a proposal to treat of granite, "porphyry," and trap as a single family, being convinced that geological philosophy must adopt this, sooner or later. But if, in separating granite from trap, I have had no other resource than a conventional criterion, founded on the assumption that granites must not "overlie" the strata, and that traps may, there is not even this expedient for separating the antient "porphyries" from the modern ones and the other traps of later date. All of them "overlie" equally, all overlie all strata, all produce similar veins with similar effects, all have been deposited under fluidity of fusion on the rocks then uppermost, and all have suffered waste, like the strata themselves; so that even a conventional distinction is impossible. And if we seek that in mineralogical characters, these cannot be trusted. There are an-

tient "porphyries" which are merely claystones, clinkstones, and compact felspars, and there are modern ones which are every thing that these are assumed to be. There are basalts and greenstones among the antient porphyries, as there are in the granites; and even the same mass often contains porphyry, compact felspar, greenstone, Syenite, and even granite of the most genuine character. And thus it must be; since the composition and origin of the whole is the same, and the differences casual; as far as casualty depends on unknown causes.

Hence is there no other philosophical mode of treating this subject than the one which I have adopted. Every other must lead to misrepresentation, assumption, or repetitions; and of the two former there has been more than enough, producing some of the greatest misstatements which have hitherto encumbered geology. Let the distinction for granite remain, for the present, what I have assumed, and there will thus be one other, to include all the rocks here associated, under this essential character, that with numerous mineralogical forms, every member somewhere or other "overlies" strata, of different ages, while in other respects they possess the characters of all the Unstratified rocks.

Of the general theory of their origin it is now superfluous to speak: but if there is a predominant granitic aspect or character in certain porphyries of apparently antient dates, and if also they contain more accidental minerals than others which appear to be of later origin, it can probably be explained by the theory already applied to granite and the simpler traps, namely, a slower cooling, permitting the exertion of more chemical affinities among the constituent earths. We may not soon precisely know why

granites and porphyries are so distinct and so complex as we find them, considering their community of origin in all cases, and of date in many. Yet the original materials may constitute the fundamental difference; as it may also be, what the result is, the superior quantity of quartz. If, in concluding, I have adopted the un-English term "overlying," it was for want of a better. The term trap cannot conveniently be so far generalized at present; and to use that of porphyry exclusively for the antient ones, is to call that porphyry which is not so, and also to exclude the later porphyries of the trap family. The porphyritic character is no distinction, and can only tend to perpetuate confusion, like Syenite; while the tendency to substitute system for fact must be discouraged in every manner.

The substances thus associated under the term of Overlying rocks and Trap, are recognised, first, by their posteriority to many, if not to all of the primary, and similarly to some, or all, of the secondary strata: secondly, by the prevailing, if not universal absence of the stratified disposition and the mechanical texture; the whole, with the exception of certain conglomerates, being of a crystalline or a chemical nature: and thirdly, by intruding, in the form of large masses or veins, among all the neighbouring rocks, while these intrusions are also frequently attended by changes in the invaded substances. The terms formerly applied to the several members of this family were neither just, nor precisely used, nor sufficiently numerous. Unwilling to change where it could be avoided, I have defined and limited those which I have adopted, while I have added such as seemed necessary. Two are entirely new: and necessarily so; because these most important rocks had either

not been observed, or not described. But no other essential innovation having been made, the different members are as follows; Claystone, Clinkstone, Compact felspar, Basalt, Greenstone, Syenite, Augit rock, Hypersthene rock, Porphyry, Amygdaloid, and Tuff. The term trap has been applied to all these substances indiscriminately, from ignorance of their mineral characters, or to save the trouble of investigation; while, as used by foreign geologists in particular, its meaning is often so vague as to be unintelligible. I have no scruple in rejecting a word which, while it is the cloak for ignorance, perpetuates it; but being a convenient generic one in topographical and general description, I have adopted it for the whole family in the secondary class. The essential minerals in all these rocks are, indurated clay, clinkstone, compact felspar, hornblende, augit, hypersthene, and common felspar. The unessential and casual ones will be found in the Classification of rocks.

The predominant substance in the members of this family, is a simple rock; commencing with indurated clay, or CLAYSTONE and terminating with COMPACT FELSPAR; the intermediate members being INDURATED CLAYSTONE and CLINKSTONE. These sometimes form the whole mass; while, at others, they are mixed with other minerals, so as to produce many of the compounds in this multifarious tribe. Chemistry has not proved a real transition between clay and compact felspar; so that the present arrangement is founded on the apparent transitions in nature; all these substances occurring together under the same geological unity, often in the same mass, and passing into each other without definable limits. The term compact felspar, is not judicious; from well known circumstances in the composition of this mineral and com-

mon felspar: but I dare not propose a change, until a more perfect knowledge shall allow us to reform a nomenclature which will gain little by partial alterations. How far the claystones may have been the produce of a certain decomposition in the other rocks, I examined in a former chapter, and need but remind the reader of it, here: but if what I then showed to be a fact is a common or general one, there is a real transition throughout the whole of these simple rocks or bases. The great diversity of colours in these rocks is applicable only to the distinction of varieties. In common clay, equally diversified, these are neglected; while the series exactly resembles that of the claystones and compact felspars. The prevailing tints are various tones of grey, red, and yellow, passing towards white; and the same substance occasionally partakes of every colour. In the Syenites and greenstones, where these minerals form a part, it has been the general and careless practice, to class the dark and grey varieties with the latter, and the pale, reddish, or yellowish ones, with the former; as the dark hard claystones have been confounded with basalt. Thus, under the same relative proportions of hornblende and compact felspar, the one has been called Syenite and the other greenstone, because the colour of the latter mineral was in the one case, pale yellow, and in the other, iron grey. The Classification has attempted to rectify this confusion; produced by assuming a distinction which was superficial, and neglecting the essential one. The iron appears to exist in three states, that of a carbonat, a protoxyde, and a peroxyde. In the first case, the rock is pale; the presence of the iron being discovered only by the rusty colour of the decomposed surface; by which criterion alone it is distinguished from compounds

containing no iron. All the grey varieties owe their colours to the protoxyde; as intensity of colour is a sufficient test of its proportions. From the peroxyde are derived the varieties of red and brown; and it is worthy of remark that the porphyritic veins found in granite, are generally characterized by these colours, while grey or black predominates in those that occur in the secondary strata.

The term BASALT has been hitherto applied to every trap rock characterized by uniformity and minuteness of texture, united to a black colour; but these do not form a mineralogical species. Thus it has included the dark and hard claystones and clinkstones, and the greenstones of a minute intermixture; while, as I have ascertained, the fine augitic greenstones, together with pure augit in a minute condensed crystallization, have equally been confounded under this term, by the multitude, more ready with names than acquainted with minerals or rocks. Let it at least be a definite rock; and as all the others are classed, it should be limited to a minute aggregate of hornblende alone.

GREENSTONE has been supposed to include the dark coloured mixtures of hornblende and compact felspar; but I have just said that colour is not a true ground of distinction between them and Syenite. But the very term itself is the produce of that mineralogical ignorance which I have tried to correct by the establishment of Augit rock. This is often a greenish substance, but the mixtures of felspar and hornblende never are so: the reputed mineralogist who has misled all that ever believed in him, appears to have confounded augit and hornblende. Greenstone must now mean the mixtures of hornblende, yet not with compact felspar alone, but with clinkstone and common felspar also, equally overlooked; while it is

evident that the boundaries of rocks so nearly allied, must be evanescent. It is under this last composition that greenstone so often possesses the granitic character; being often, when separated from its connexions, undistinguishable from specimens occurring in granite. In many cases, under an apparent resemblance, the existence of quartz in the latter, forms a distinction, though not a certain one: while the presence of sphene and other minerals is not sufficiently constant for this purpose. It is one of the cases of the intimacy of character among unstratified rocks far distant in geological time.

I have shown that the old distinction between Greenstone and SYENITE is a superficial and incorrect one; but this term must be retained for the sake of the triple and quadruple compounds in this family which become, mineralogically, granites; while I have rescinded it out of that one, as I have done greenstone both from granite and hornblende schist, to prevent future geological confusion. If I retain it for the binary compounds of hornblende, I would willingly limit it to those with common felspar, and in which this latter predominates; while it is plain that its limits towards greenstone must become evanescent. But averse to more innovation than is avoidable, it may remain as the name of any binary compound also, in which clinkstone or compact felspar similarly predominate, while equally then graduating into the analogous greenstones.

If the distinction of AUGIT ROCK is new, it is much needed, as it appears to be very abundant in nature, and, in my own experience, more so than greenstone; with which it has been so confounded. It may be difficult to distinguish Augit from hornblende, when in a minute state and much intermixed; but every mine-

ralogist ought to be able to make the distinction, in any rock. Like greenstone, by the predominance of the felspars over the augit, it assumes the aspect of a binary Syenite, to careless mineralogists; while in minute intermixture, or else, as pure augit in minute condensed crystals, it puts on the aspect of a basalt. I have already said that many of the reputed basalts are of this nature. Augit rock presents an interesting analogy to the produce of volcanoes, in which this mineral is far more often present than hornblende.

I have equally been obliged to introduce the new term HYPERSTHENE ROCK, for an important member of this family, never before described, or even suspected; especially as possessing geological characters very different from the other associated substances, while consisting of mixtures of Hypersthene with either kind of felspar. It is a rare rock, or else it has ofted been overlooked, or confounded with ordinary greenstones, as it had been in Scotland until the publication of The Western Islands. In Sky and in Airdnamurchan, it forms extensive tracts, and probably abounds in Greenland and Labrador. In general, it presents the external large features of granite; rising into spiry summits, and exhibiting a durability very rare among the members of this family. It is equally disposed in huge convex beds, separated by actual fissures, or by their indications; while it also divides into prismatic and cuboidal masses. It is also found in large spheroidal concretions, extending to fifty feet and upwards in diameter; but I have observed no examples of the prismatic or columnar structure. It occasionally exhibits the same tendency as granite, to decompose in crusts; and thus presents an occasional schistose structure, which, as in that case, may be only the result of weathering.

The general structure is granitic; varying from that of the coarsest granite, through all possible varieties, to a degree of minuteness such that the particles are scarcely distinguishable by the eye; and thus, in many of the intermediate states, resembling common greenstone, with which it had been confounded by mineralogists, who had even walked over miles of it. Sometimes containing superadded distinct crystals of felspar, it resembles the porphyritic granites, and it also presents one other general resemblance to granite, in occasionally containing garnets; while, lastly, it sometimes resembles gneiss; being fissile, from the parallel position of the crystals of hypersthene. It resists decomposition powerfully; appearing to undergo no waste, generating no soil, and thus presenting an aspect of barrenness unequalled by any other rock; while the indestructible hypersthene continues to project on the surface, so as to cause a singular roughness by which it is easily recognised, by the touch, or even by the feet, blindfolded.

The term PORPHYRY is applied to a rock in which crystals of common felspar are imbedded in a simple or a compound base. Hence the numerous varieties noticed in the work so often mentioned. But this structure does not form a geological distinction, nor accompany any steady difference of character among these rocks: occurring, even as an accident, in the most recent traps, as in the most antient, where the prevailing character is simple, and also in the other members of this family here enumerated. To some of the recent porphyries, the term Trachyte has been lately applied; being extended also to other associated rocks, and even to Pumice. I am not aware of any peculiar advantages in this contrivance; which, like the rest of this Gallic neology, seems to serve no pur-

pose but that of creating mystery, by appearing to imply knowledge unknown to those who are content with common phraseology. He who does not explain himself in received language, wishes to appear more profound than others; and he who cannot, may fairly be suspected of knowing less. The rocks of this family especially connected with the primary strata, are generally porphyritic, though not invariably so. Though the antiquity presumed from this connexion may often be deceptive, they present a very general peculiarity of mineral character, often approaching to that of granite; the base being frequently granitic, of mixed minerals, and when simple, consisting of compact felspar, exclusively; while they also contain metallic veins not occurring among the recent traps. The porphyries of these are far less varied: but I must refer to the Classification for what I need not here describe again.

The ignorance, or system, of the German geologists had classed the older porphyries among the stratified rocks; but they possess all the geological characters of the more recent and ordinary traps, excepting as these may have been modified by their peculiar connexions. The supposed strata, when superficial, are rigidly analogous to those of Trap; and the fallacious appearances of interstratification, are either the produce of beds shaped by the primary strata in contact, or conformable veins, or else, as in granite, the result of the laminar concretionary structure on the great scale. The practical student who has been bewildered by the difficulties attending the great deposits of antient porphyry as they have been hitherto described, will be no less thankful for the facility afforded him by this account of their real nature, than the mere reader, for being thus saved pages of unintelligible description.

The AMYGDALOIDS demand a few words, though the origin of the imbedded nodules has been formerly examined. In the analogous lavas, which are cavernous and empty, or cavernous and filled with various minerals, the caverns have been caused by the extrication of air or steam during fusion; while, under a pressure preventing that extrication, there are produced solid, instead of scoriform lavas. In the amygdaloids, superficial empty cavities sometimes result from the waste of the included minerals under exposure; but, in other instances, they are deeply situated in the mass, where neither air nor water could have had access, or whence, at least, the supposed nodule could not have been removed. And as the interior of such cavities is in all respects similar to those of the volcanic scoria, while they are also often elongated, and even contorted, under a corresponding elongation or contortion in the whole mass of rock, it is evident that these cavernous rocks have not been subjected to a pressure capable of preventing the extrication of air; as I need not repeat that they could acquire this character from no cause but fusion.

It has often been said, by those who have written so much on what they did not know, that the cavernous structure was a test to distinguish between the traps and the volcanic rocks. But it is not so, unless the Little Cumbray be supposed the remains of a volcano. Had even the rock of Edinburgh Castle been examined by those who wanted no opportunities, this assertion could never have been made. The Claystones of that island are often as perfectly cavernous as the scoriform lavas, and so light as almost to float on water; while it is superfluous to say that the caverns have been always empty: their elongated or tortuous forms and interior varnished surfaces, moreover, rendering them

undistinguishable from the cavities of volcanic scoria. And this island must be formed of trap, if the neighbouring tracts in Bute and on the Ayrshire coast are; because they are all, unquestionably, parts of one general deposit. The same argument is indeed equally derived from all the amygdaloids; under the explanation which I formerly gave of the origin of the imbedded nodules. And if this is therefore no such test as has been asserted, it is not true that the trap rocks have been necessarily subjected to great pressure, or, as inferred, that they have all been formed beneath a deep sea. Nor is there even the imagined necessity for this supposition on the part of these superficial system-makers; since the general question of the igneous origin of trap is not implicated in the establishment of that opinion. Many rocks of this nature may have been thus formed, beneath, or among, the strata with which they are now associated above the level of the ocean, having thus also elevated them from beneath the water; as the volcanoes of Italy and the Coral islands have moved the superincumbent strata to their present positions. But it is also a mere dispute about terms, to refuse the name of submarine volcanoes to these eruptions of trap. They are such in every essential point, if they do not now eject fire or smoke; they are extinguished volcanoes, as much as are those tracts in Italy where similar elevations of the strata have occurred, and where the volcanic action has ceased. And if the limitation of formations of trap to the sea, while the land has escaped them, is absurdly hypothetical, it is equally unnecessary; since the pressure required to prevent the extrication of air may have taken place on the land as well as under the water; as is fully proved in Volcanoes, by the existence of solid lavas, which, in other situations, would be

cavernous, and which are sometimes both solid and cavernous, according to their depths in different places. Thus may the Trap rocks have been formed among the secondary strata, after their elevation, or on the dry land, as well as under the sea: while the usual process of waste would first remove the portions peculiarly characteristic of volcanoes, or those which, being superficial, are also the most cavernous. And that this has actually happened in volcanic districts, is indicated in Sardinia, and in many other places. Thus, antient volcanoes, terrene as well as submarine, may have been the origin of the present trap rocks; as is rendered further probable by their repetition in the same place. Thus also might the secondary strata remain covering the volcanic rock, until removed by subsequent waste; and such may be the origin of the traps with flat surfaces, occupying the summits of mountains; just as a future waste of the Apennines would expose rocks truly volcanic, with all the characters of our own traps.

This view is confirmed by the circumstances attending the trap rocks of Transylvania; while the natures of the substances render the argument equally applicable to the whole tribe of these rocks. In this very extensive tract there occur porphyries, of which some almost assume the granitic character; and it contains a Solfatara, still hot, while, at Budoshegi, there are also the marks of a crater. There can be no doubt that these volcanic indications belong to the fires which, at some remoter period, produced this tract of rock; and it is confirmed by the analogous case of the Andes, where the long chain of extinct volcanoes which includes Popoyan, is situated in a similar chain of the same porphyries. Nothing more seems wanting to

prove the identity between the trap rocks and the volcanic ones, and the common cause of both.

The last member of this family is TUFF, or tufo; while, presenting some important differences of geological origin, I must here distinguish what geologists have always confounded under a mineral term, with the usual neglect of causes, or of geological philosophy. There are conglomerates of trap under this name, that are merely portions of the old red sandstone, in which, more or less of the casual materials have been derived from antient traps. Geology requires that they be separated, and ranked as varieties of that sandstone. Again, it is not unusual at the junctions of trap with the same sandstone, to find that the fused rock has invaded the conglomerate, while, in altering some of the fragments, it has given to the whole the aspect of a real trap conglomerate or tufo, yet only in the eyes of those who cannot make the distinctions which appear never yet to have been made as to this case. If Geology is to mean what it ought, this must also be rescinded from the trap tuffs, while its place in the system is obvious. There remain then but two varieties that I know of, to be truly placed under this title; and both consist of mixed fragments of all sizes, rounded or not, with trap sand, often so little adhering as even to leave interstices, though these are sometimes filled with infiltrated carbonat of lime. Each kind is covered by or alternates irregularly with solid trap, as they also sometimes occur in apparent veins, further containing occasional lignites, as is hereafter explained. Their fusible nature, added to their mere existence as tufos, proves, that however connected with solid traps, they have not been subjected to much heat, while their non-conducting power will explain their escape under

such circumstances. I cannot doubt that some of these were originally, eruptions of volcanic "ashes," or volcanic mud; and they confirm that identity of origin between volcanic and trap rocks so often here inculcated. And, from what I can observe, the other kind appear to have been formed out of casual and local fragments, produced in the usual manner from antient traps, and subsequently overwhelmed by new eruptions. At home, this case is evident in Canna; and if I cannot find it distinctly recorded by others, there is an analogy to support it in that case of granite already quoted at Predazzo.

The great features of this whole family present examples of every species of outline found among other rocks, with some which seem peculiar to themselves. And if sometimes regulated by the nature of the different leading varieties, considerable differences in the outline of a country sometimes occur, where the rocks are the same; and the reverse.

It is not unusual to find a land of low and tame undulations, consisting solely of claystone, porphyry, and greenstone, while the same rocks produce complicated groups, or ridges, or single mountains, of considerable elevation and of distinct rounded, or conoidal forms, rarely exhibiting any other abrupt faces than those produced by the casual position and flow of water-courses; the causes of these tame forms consisting in the yielding nature of the materials, and in the ready disintegration which the rocks undergo. Thus, by the gradual descent of the fragments, the original asperities are softened and the cavities filled up; while, the whole progress of the change may often be traced, from the sharp and projecting face or pinnacle, to the even and gently swelling declivity. Where inimical to vegetation, or when the descent of

the materials is so rapid as to keep it in check, the surface is formed of such fragments, to a great depth; while, more generally, being productive of fertile soils, the whole is obscured by the vegetable covering. In the older porphyries, displaying projecting rocks and precipices, it is often difficult to distinguish between the mountains and those formed of the primary schists; the characters being often also very striking, as in Glenco. The more durable varieties of trap sometimes also exhibit the peculiar spiry forms of granite, as they resemble it in other respects; and I may refer for an example to the Cuchullin hills of Sky.

But they also present some peculiarities scarcely found in any others; among which is that of distinct masses insulated on the surface of a district of stratified rocks, or crowning, in single summits, some mountain of another substance. These occur indifferently on all other rocks, not excepting granite; while they consist, either of the older or of the more recent members of this family. Ben Nevis presents a remarkable example of an antient member of this division, lying thus on granite; and Morven displays equally striking instances of a more recent one, covering the modern strata which contain coal. In other cases, the mountain outline consists of a succession of terraces, either horizontal or slightly inclined, bearing that resemblance to a gigantic staircase whence the term trap is supposed to have been originally derived. This appearance arises from the succcesive vertical fracture of the beds of which such mountains are composed; and where only one such fracture occurs on the summit of a hill, another peculiarity, by which these rocks are easily recognised at a distance, is also produced; in the long and rapid

slope resulting from the fall of the materials. These latter features appear to occur peculiarly where these rocks are incumbent on the secondary strata; but they are not limited to one particular member of the family, since they belong to basalt, to greenstone, and to claystone.

The rocks of this family are found incumbent on every other rock from granite to chalk; as the recent members sometimes also cover the more ancient ones in a similar manner. But the compound porphyries, those with a base of compact felspar, and the simple compact felspars, are, generally, in contact with the primary rocks; yet not exclusively, since the most recent traps covering the secondary strata, sometimes also occupy the same position, though these particular porphyries are seldom found upon the secondary. Perhaps they never thus occur in extensive masses and with decided characters throughout; but, as many of the most recent members approach in character to those which appear more antient, it is impossible to acquire absolute certainty in any case, without a critical examination of all the circumstances.

If the forms of these great masses are very diversified, so are their lateral extent and depth. They sometimes cover a great range of country, as in Spanish America; while, even with us, the Cheviot, the Campsie, the Pentland, and the Ochil hills present considerable tracts. On the other hand, they frequently occur in minute patches, or as insulated mountain summits, the examples of which, in Scotland, are too common to demand quoting. Their depths are equally various, that of the Cuchullin hills reaching to 3000 feet at least; while in Scotland they range from that to a few feet in thickness; though in this case, as might be expected, their lateral extent

is inconsiderable. The peninsula of India, and South America, present well-known examples of enormous depth as of extent.

Of their original forms and dimensions, we have more reason to be doubtful than even of those of the stratified rocks. Independently of those usual causes of waste to which all rocks are subject, many of them appear peculiarly susceptible of decomposition. Hence their frequently insulated state, and the consequent difficulty of conjecturing the nature of many of the independent masses which occur. From this, and from their peculiar relation to the stratified rocks, arises the difficulty of determining their relative periods of deposition. Excepting a few particular cases, if it were asserted that the whole were the work of one interval of time, it would not always be easy to find arguments to refute the opinion. It is repeating a former statement to say, that extensive losses of the secondary strata are to be traced, and that these never covered the primary in every part; whence a mass of the overlying rocks deposited on such a surface, might be in contact, in one part, with granite or gneiss, and in another, with one of the latest of the secondary strata; causing a fallacious apparent distinction in the time of deposition. And as these rocks present signs of extensive waste, perhaps even in a greater degree than the stratified ones, it is evident that two masses might be esteemed distinct, and distant in origin, though originally one, should the discontinuity occur between the portions lying on the secondary and those lying on the primary strata. The fact itself is common, and easily proved; particularly in the case of the insulated hill summits just mentioned. To what extent indeed that waste may have existed, it is impossible now to know; so that it is

often equally impossible to determine whether there is any difference in the æras of the several deposits of trap, or whether they may not, according to this hypothetical statement, have been all parts of one general formation. I have, however found the means of proving that such deposits have taken place at different and distant times, and that some of them are of an origin prior to the formation of the secondary strata.

In the lowest red sandstone in different parts of Scotland, there occur imbedded masses of these substances, in considerable quantity and variety, and bearing the marks of attrition. These materials must have been derived from primary rocks; and thus the existence of trap formations prior to the deposition of the secondary strata is established. And lest it might be inferred that these were merely the varieties of granite which I have described, I must remark that many of them are amygdaloidal, and some cavernous; as they all resemble the later members of this family. There are circumstances in the veins of these substances traversing the primary rocks, which lead to the same inference of antiquity as to them, if they do not absolutely prove it, since they rarely if ever occur in those which traverse the secondary strata. Their base is that compact felspar, generally coloured by the peroxide of iron, which distinguishes the well-known porphyries, while the crystals of felspar are rarely absent, and commonly abundant, compared to their occurrence in the later veins. They also frequently contain mica and quartz, which are rare in the later, together with pinite, which has never yet been found in these; presenting other characters less easily defined than recognised, while frequently also assuming a granitic character. And if such veins never are traced from the primary rocks into the secondary,

while those of a different aspect, connected with the masses that lie on the secondary rocks, pass into the primary strata, the fact of at least a relative antiquity is ascertained; and thus also there must be masses equally distant in time, since all veins thus originate. In the later ones indeed, it is often easy thus to trace the veins; while, as in granite, the parent masses may in other cases be invisible, or may have disappeared in the progress of time; though, even in the apparently antient, this connexion is often to be discovered. These then might be placed in the primary class, if any one is desirous of such a distinction: and they would thus rank, in time, with the granites, with which their essential connexion must be sufficiently apparent.

The same causes render it difficult to determine the number of periods of production in these rocks; though there should have been many, not only in the later traps, but in the "porphyries" of a higher antiquity than the secondary strata. I have shown that, in these cases, no stress can be laid on the circumstance of contact with particular strata; so that, as in granite, we are limited to the test derived from intersecting veins. And when these are found to cross, so that the first is also shifted by the second, there is evidence of a decided posteriority in the latter, while we can equally infer that there have been at least two formations of overlying rock among the primary, as there have been among the secondary strata, and both of them before the foundations of the latter were laid. If there have been more than two of this early date, I know not that I have produced proofs to satisfy myself; yet they may have occurred to others, since the fact is not improbable. It is a much more difficult question at present, to ask whether the granites are all prior to these early

examples, and what are the relations of date among the several granites and the different porphyries. I have never seen a granite vein traversing a porphyry, and I know not that any one else has; while if this be a fact, the oldest porphyry is more recent than the latest granite. Yet I fear that this will ever be one of the insuperable difficulties in this great family of the unstratified rocks; because, under what I have shown respecting the frequent community of character between granite and trap, under the changes which a granite mass undergoes in its veins, under the fact that actual porphyry does occur in granite, as a casual change in the crystallization, independently of that gradation between the two in the cases of porphyritic granite and granitic porphyries, and lastly from what we know of the chemical causes of these variations, we never can be sure that a mass or a vein of porphyry may not be the mere local variation of a granite. And thence perceiving that geological difficulty which geologists have never yet contemplated, because they have ever observed and reasoned as mere mineralogists, upon specimens and not on geological principles and causes, the reasons for treating of all the unstratified rocks as one family become still more apparent, if we intend to investigate geological science, and not to collect and examine mineral masses, imagining at the same time that we are learning and teaching Geology.

If, equally, among the traps in the secondary strata, no proof of two or more deposits is derived from their contact with beds of different dates, I must now remark that the superposition of one mass above another, even if of different kinds, affords none. These may have been made in succession during one interval; while differences of composition and character equally prove nothing, since they occur, in a mixed and graduating

manner, in the same mass, and even in the same vein.

Yet a succession of at least two, if not of more such formations is proved, as in the former case, by means of veins, traversing masses or intersecting other veins; while I think that I have traced more than two such sets of veins; whence we can infer an equal number of masses, or distinct productions of trap. A different proof of such a succession of productions occurs in Canna, where beds of trap alternate with strata of a conglomerate containing rounded nodules of similar materials. These, it is plain, must have been derived from previous masses of a similar rock; while it is equally evident, that there must have been an interval of time between the two, to produce the attrition and accumulation in question. The last proof of this succession of trap at distant intervals is that, already noticed, where the lowest sandstone contains, among other materials, many varieties of this family, such as greenstones, porphyries, claystones, and amygdaloids; while, being covered by masses of trap, two productions, and of extremely remote date, are thus proved. But further, as both in this case and in that of Canna, the superincumbent masses are traversed by trap veins, there is absolute evidence of three productions at distinct periods, should the triple set of veins in Airdnamurchan not be satisfactorily demonstrable.

If the former indispensable general remarks on the Unstratified rocks have anticipated much of what I cannot nevertheless avoid noticing in the histories of the different families, though under some repetition, the two last cases are those whence I deduced a most important conclusion respecting the repetitions of productions of trap in one place. The trap conglomerates of the red sandstone series, are limited to certain

portions of the general district formed of these strata; and the more recent masses of trap which cover and intersect them, are also limited to the same space. In Canna and near Oban, the rounded nodules betray other marks of long exposure than their attrition, in the loss of their superficial amygdaloidal nodules; both facts showing that these tufos and trap alluvia, originally limited to one place, have been consolidated by fresh formations of trap at a distant interval of time, and in the very same spots. And this conclusion is, to establish an important point of resemblance between the trap rocks and those of volcanic origin; or of proving, that like volcanoes, eruptions of trap have been repeated at the same points. The complicated successions of veins in Airdnamurchan afford further evidences of the same nature; as similar ones might be pointed out in many other places. Combined with the local and limited nature of the trap rocks, these facts serve to extend that identity, rather than resemblance, between volcanoes and the sources of trap, which is evinced by every fact and feature in the history of this family.

If the trap rocks are generally associated with the secondary strata, this rule is not exclusive, yet the conclusion to which it leads, is not very important. If the secondary strata covered all the primary at the time of the formation of the trap, it must necessarily be always thus associated; and its present existence above them only proves that it has protected them from that waste which may have removed other parts of the surface. But its contact with the primary does not prove that the secondary may not have once existed even in those situations; as the recent period of its formation might have admitted of the intermediate removal of the portions now absent in those places.

Besides the superincumbent masses thus discussed, the trap rocks occur in beds, alternating with, or surrounded by the stratified ones; while I need not distinguish between the primary and secondary strata; as the same appearances are found in both, though much most frequently in the latter. These beds vary in thickness and in frequency of repetition; forming, at times, mere laminæ, at others, considerable masses, but being commonly, both limited and irregular. When carefully examined, and through a considerable extent, they present many peculiarities by which they are distinguished from the associated rocks. Though often appearing to be parallel, that parallelism is either imperfect or not persistent. They are often, it is true, so situated, that sufficient access becomes impossible; but, I have described cases in Sky, where even after maintaining their regularity for a mile or more, they have given indications of their peculiar nature; by intersecting the same strata to which they were elsewhere parallel, and then holding a similar course between another pair. In other cases, an apparent parallelism is proved, on a rigid examination, to be fallacious; while in others again, the same vein which intersects a large mass of strata, loses that direction at another point, and runs parallel to them; thus also producing the deceptive appearance of an alternating bed. These alternating masses must therefore be considered as veins holding a course parallel to the strata in which they lie, as in the case of granite, and not as beds deposited in alternation with the strata. And this is further confirmed by the communication of an overlying mass with such apparent beds; which are thus shown to be veins in a peculiar position, diverging from it, as the more common transverse veins do from similar masses. Such apparent beds also themselves ramify: giving out mi-

nuter branches into the surrounding strata, or else coalescing and being again separated; neither of which true strata ever do: while, lastly, they are found entangling fragments of the surrounding rocks, which remain insulated in them, under those fractures, incurvations, and changes of quality, which have been so often noticed. It is almost unnecessary to say that this description equally applies to the supposed alternating beds of porphyry among the older rocks; but, among these, it appears to be a less common occurrence. These parallel veins explain a not unfrequent case in which trap presents a still more deceptive appearance of stratification, by occupying the surface of the country and maintaining an apparently equal thickness, with a general conformity to the secondary strata on which it lies. Salisbury craig near Edinburgh is a well known example of this; but a much more perfect one occurs at the Garroch head in Bute. It is plain that this has arisen from the loss of the superior and secondary strata in which these beds had once been included; and thus the accuracy of their forms is explained, together with their present superiority of position. And any doubt of the truth of this explanation is removed, by actually tracing the waste of the strata in such cases, and by finding portions of them still remaining after the greater part had disappeared.

There is one distinct case, however, in which these rocks may and do occur in the shape of strata, without forming veins, or having intruded among the stratified rocks. I have elsewhere shown that the effect of the proximity of trap to shales is such as to convert them into substances resembling basalt; and thus real basalts are sometimes interstratified with siliceous schists, with cherts, and with jaspers, derived from the

action of heat on the original strata. And if I have also proved the partial fusion and conversion of schists into basalt, greenstone, or porphyry, such cases need not be limited in extent; while it is easy to see that a body of various strata, thus acted on, must exhibit results proportioned to their respective capacities for fusion. The most fusible material becomes converted into basalt or greenstone, or, under less heat, into siliceous schist, the argillaceous limestones into chert, and the sandstones into other analogous compounds; while the infusible clays become jasper, or, like the red iron clay so common among these rocks, retain their loose texture. This hypothetical case actually occurs in Sky, on an enormous scale; and it is only to extend the powers of this cause, even far within the limits which it has obviously exerted in nature, to explain many of the examples of stratification in trap, to which the former solution does not apply. As a striking example in point, I may again refer to the porphyry near Campbelltown; where the intermixture of fragments of schist, and their gradual conversion into the unstratified rock, are perfectly obvious. A phenomenon precisely similar has been since observed at Schemnitz in Hungary, and will, no doubt, be oftener seen, as observers learn to follow where they had never known how to lead.

The last form in which the rocks of this family occur, is that of veins. These abound equally in the most ancient as the most recent traps, and are often indeed the only remaining traces of the former existence of extensive masses. Varying exceedingly in size, the largest ones bear such a relation to the overlying masses, that I should have already noticed them had I not considered that they would be better understood in this place.

Occasionally there occurs a mass of trap, which instead of being superimposed on the strata, is placed laterally respecting them, or else covers, in one part, the same body to which, in another, it approximates in that manner. Examples of this occur in Sky and in Morven; while a careful examination shows that the lateral approximation is an intersection; so that the mass is, properly, a vein. These intersecting masses are often of enormous dimensions, extending even for miles; and, like the smaller veins, they reach to unknown depths; probably forming a communication between the overlying masses and bodies of similar or greater dimensions, situated beneath the strata. That such masses do exist beneath, as well as above the stratified rocks, is evinced by the circumstances often attending veins, were it not even a necessary inference from the general theory of their origin. In these cases, the intersected and bent or broken strata are also turned upwards, as if by a force acting from below; indicating the place of the parent mass and the progress of the intruding material upwards. Bute presents an excellent example of this fact. In Sky and elsewhere, strata are also found bent over an interior or subjacent mass of trap, of inaccessible depth: displaying, distinctly, what the theory had inferred; while, in other instances, they have been broken as well as bent, so as to have given exit to the subjacent material. This particular modification is obviously analogous to the cases of granite, which trap resembles in so many other particulars; and it has given rise to the inference formerly examined, that, in the predominant cases, it has been protruded from beneath in a liquid state; being thus analogous to those products of volcanic eruption, with which its mineral characters correspond so nearly.

[illegible] veins vary in size from a breadth [illegible] thickness of a thread; these [illegible] occurring, as far as I have seen, only [illegible] strata. They do not often ra-[illegible] occurrence is most frequent in those [illegible] claystone, and basalt. They are gene-[illegible] and often remarkably so, though occa-[illegible] and even curved at right angles. The [illegible] they traverse without undergoing any [illegible] of size, is sometimes very considerable; [illegible] to many miles; as is the case near [illegible] Scotland; while, in other instances, they [illegible] after they quit the parent mass. As [illegible] originate in visible masses, and termi-[illegible] surface after a certain course, we might [illegible] their depth downward was also limited, even [illegible] not abundant evidence of this, everywhere. [illegible] that because, in some cases, their depth has [illegible] reached by miners, they must be indefinite [illegible], as was done by writers still quoted for [illegible], is to be ignorant of the nature of veins; [illegible] is to forget, that while a horizontal extent of a few hundred yards is a very short course, the same dimensions downwards, equally limited, would carry them out of the reach of mining operations. For other obvious reasons, this is the supposition of ignorance; as their depth must inevitably be regulated by the position of the parent masses. If there are veins which cannot be traced to any source, we may still infer the same superficial immediate origin, if we choose, because we know that such masses often disappear under the usual waste. In Sky, for example, where a great number of parallel and similar veins exist together in one spot, only one or two remain connected with the overlying mass, which has evi-

dently disappeared over the remainder of this tract. But such superficial connexions, visible or inferred, are by no means necessary, since, as in granite, many trap veins are connected with deep-seated bodies of rock only; as they sometimes also are with superficial masses at the same time; the vein uniting the productive source, in this case, with the portion which has overflowed. This could not be otherwise, from the very theory; and the real, prime source of the veins is essentially below, though the apparent and immediate one should be in a superficial mass. Hence there may be trap veins which never were connected with a superincumbent mass; since it is not necessary that even a volcanic lava, splitting the surrounding strata, should become an open stream. It is almost unnecessary to say that these veins cross the strata at every possible angle; but these being generally high, and very commonly vertical, it is an additional indication of their probable origin in deep subjacent masses.

The matter of the veins is nearly as various as that of the rocks already enumerated; every variety having occurred to me under this form, except hypersthene rock. Yet the observations on this substance, as yet limited to my own, are not sufficiently extensive to allow of so improbable a negative; and it will doubtless hereafter be proved obedient to the general laws. Had Sky been other than it is, I would have found these veins long ago. If, in general, there is but one mineral variety contained in a given vein, there are exceptions to this rule; as I have formerly pointed out veins containing basalt, greenstone, porphyry, and amygdaloid, placed in parallel laminæ, with others where these various substances were intermixed in an irregular manner.

Turning now to the chemical effects produced on the adjoining rocks by these veins, there are few changes in those where the overlying rocks appear to be of the most distant date; as are the porphyries connected with granite and the more antient primary strata. To remind the reader of the cause, is to confirm the general theory. The strata traversed or invaded by the more antient porphyries and traps, are precisely those which owe their condition to heat, and which have therefore already undergone nearly all the effects of which they were susceptible. Yet, even in these cases, I have observed the induration of the strata in contact, and the occasional entanglement of portions of the surrounding rock; as in a porphyry vein in Glen Fernat, thus including fragments of quartz. In the more recent traps, these several circumstances are common; and they present indeed some of the most remarkable appearances which characterize and distinguish these substances. Thus, ordinary sandstone becomes indurated into compact quartz, calcareous and argillaceous sandstones are converted into one species of chert, and argillaceous limestones into another, pure limestones become crystalline and large grained, with the disappearance of organic remains, while the shales are converted into siliceous schist. Some of the ordinary clays become red from the ultimate oxydation of their iron, while others are converted into that jasper so often confounded with pitchstone. Thus is pyrites occasionally decomposed, and coal either charred or converted into plumbago: while these changes occur equally, if to different extents, whether the contact be that of masses or veins, and while, also, they are all such as would be expected from the action of heat; coinciding therefore with the various phenomena

d, to prove that origin for these not now repeat. I have else- nor appearances of an analo- quisition of a granular or e shales; while I may metimes undergo an spheroids are of g in the shales while in rare cases, es locally arranged, yet oincident with the faces of a rking, what is important in the the power of heat to produce its on, as I have indeed elsewhere proved by xperiment. To these proofs of the action of , are superadded marks of violence, often extremely conspicuous. If I formerly observed that fragments of the including strata were often entangled in the neighbouring and intersecting rock, they are often of enormous size, while they also bear the marks of further fractures, and of curvature, as in Sky; some splendid examples having been figured in the account of the Western isles. That such effects are the result of violence, is proved by the different action exerted on yielding and on refractory materials; the one, as I have formerly remarked, being bent, while the other is broken. The same circumstances occur in the veins; the passage of which through soft or through hard rocks, or in directions parallel or tranverse to their natural divisions, are indicative of a force similarly exerted, but varying in its effects according to the opposed resistance. In both these cases, and in the veins more particularly, the displaced and insulated parts could often be refitted if we could restore the fluidity of the trap: the corre-

spondences remaining perfect. Of this, a very beautiful example occurs in the valley of Coruisk, in Sky. If minute and numerous fragments of the including strata are often enclosed at the immediate contact, or in the walls of the vein, while also limited to these, the same circumstance occurs in the larger masses, but with variations attended by peculiar interest. In this case, the fragments are often partially fused, and thus far converted into the substance of the invading rock ; the larger mass having effected that change to which the smaller was inadequate. The schistose rocks thus often present a further very instructive appearance ; the laminæ being separated, and their intervals filled by air bubbles ; so that the thickness of the entangled portion is increased, exactly as it is by heating it in an ordinary fire. The plates of that work on the Western Isles contain many drawings illustrative of these, as of other facts described in the present book ; and I may here refer to what I cannot reprint.

More minute details, however interesting, would extend this chapter to an unwieldy length. Yet I must remark, that although I have here preferred domestic examples, because I desire that every one may be able to examine my evidences, the same phenomena have at length been observed in other parts of Europe, by those who can now discover what they have been taught to see and understand. The last appearance quoted, which so few have chosen or have been able to see, even when placed before them, has been now confirmed at Plauen in Saxony ; the shale of the red marl has been found converted into siliceous schist at Blaua Kuppe in the same country, as the magnesian limestone has into chert, in the Vicentin, and as others have been found crystallized into white marble in the Pyrenees. It is *satisfactory* to find that there are persons who will be

taught, among the number who had determined that there was nothing more to learn; and that the science is thus benefited, though it be only by the repetition of identical evidence. If, at times, these rocks exhibit no traces of a peculiar configuration, breaking indifferently in any direction, and with faces of no character, this is more particularly true of the syenites and claystones; though occurring, perhaps to an equal extent, in the porphyries, of whatever date. In other examples, they present an irregular and angular fracture, so as to leave acute projecting edges or points; as seems more particularly true of augit rock, and of the analogous greenstones. Very rarely, they are disposed in curved or straight beds, subsequently divided into irregular prismatic masses; as I have already observed of Hypersthene rock. This feature is not however peculiar to the more antient traps, as some have supposed; since that of the Corstorphine hills, which lies above the coal series, can scarcely be distinguished from granite in this respect. The large laminar structure is also not uncommon; occurring in the porphyries of all ages, as well as in the syenites and claystones. It is sometimes vertical and very distinct, at others, horizontal; being then attributed to stratification, as the similar forms in granite have been, by those teachers of geology whom I am too often compelled to notice. I need not repeat the grounds of distinction; and I have already shown where there is a remarkable affinity with gneiss, in the case of hypersthene rock.

The vertical division into irregular and angular parts, is one of the most striking configurations of these rocks; occurring in the most antient porphyries and claystones, as in Glenco, but most conspicuous in the traps that are associated with the secondary strata, including basalt, augit rock, greenstone,

and claystones. It is sometimes such as to present an imperfect prismatic appearance; whence it gradually passes into the complete columnar structure, the most remarkable of all the modes of configuration presented by any rocks, which, though already generally described, requires some further detail here. The columns sometimes adhere so as to be inseparable by mechanical force; though ultimately separated by the action of the weather. In these examples, they sometimes pass, either end-wise, or laterally, into the amorphous or the prismatic rock; while that portion only which constitutes the visible surface presents the columnar appearance. At others, the columnar portions form distinct beds, separated by intersection from the amorphous part, both above and below; while a columnar bed is even sometimes cut through at right angles by a similar intersection; the adaptations of the columns still continuing so perfect, that the direction of a single column remains unaffected. It is equally remarkable, that where portions of the secondary strata are entangled among columnar beds, as in Sky, that continuity of character is not affected, nor the regularity or forms of the columns changed, even at the points of contact. But these columns are sometimes also perfect, and easily separated by sufficient mechanical force; their forms, in this case, displaying different degrees of regularity. In a few instances, being geometrically straight and true in all their parts, they present those beautiful objects, too often and familiarly described to require notice here. Sometimes, the columnar parts, instead of being parallel and in one plane, are so situated that the termination of one is approximated to the middle of another; so that the extremities are compressed and extenuated, as if they had been forced together when in a soft state; the whole mass bearing a lively resemblance to a peat stack.

The columns vary in the number of angles, from three, even to eleven or twelve; the medium polygons, from five to seven being prevalent, while, in the higher ones, the angular forms almost vanish. In all cases, the sides are in contact, or so little separated as barely to admit of the infiltration of carbonat of lime, if present; a striking point of difference, as formerly observed, between them and the prismatic bodies which result from the cracking of dried clay. No case of a single polygon thus aggregated has yet been observed; the various forms occurring together, and the adaptations being produced by the combination of many different prisms. The columns are sometimes continuous, at others jointed, obliquely or at right angles: being also ocasionally cracked, without the appearance of regular joints. These, when they exist, vary much in frequency; being sometimes repeated within the space of a few inches, at others, only after many yards. At times they are mere divisions, the surfaces above and below remaining flat; while, at others, they are irregularly undulated, and, more rarely, adapted by a mutual convexity and concavity; the latter generally belonging to the lower surface. In a few rare instances, as in the Giants' Causeway, each angle of the inferior joint is prolonged upwards into a denticle overlapping that of the superior one. Their sizes vary exceedingly, both with respect to length and diameter: the longest which I know, in Sky, reaching to about 400 feet, and the shortest, in Morven, not exceeding an inch; while in diameter, those of Ailsa measure nine feet, and those of Morven, an inch, or less. Intermediate sizes are, of course, more prevalent.

With respect to position, they are found placed in every manner, from the horizontal to the vertical angle, though attracting most attention in these latter cases, from their resemblance to the efforts of architecture

and claystones. It i[illegible] ght; being sometimes imperfect prisma[illegible] han one plane; while, passes into the co[illegible] ongregated together in remarkable of all [illegible] also irregularly imbedded by any rocks, [illegible] Staffa. Of one variation scribed, requir[illegible] but a single example, in sometimes n[illegible] rock being disposed in im- cal force; [illegible] convex surfaces of many of the we[illegible] and cracked into polygons pass, eith[illegible] septaria; the divisions being or the p[illegible] contracting downwards, while consti[illegible] the same time, horizontally appe[illegible] in slabs. The whole appear- dist[illegible] which occurs in the superficial ph[illegible] metals after fusion; the indurated be[illegible] consequence of the greater expansion a[illegible] s[illegible]

[illegible] structure is not limited to one mem- [illegible] though vulgarly appropriated to [illegible] occurs even in the antient porphyries, [illegible] clinkstone, claystone, augit rock, [illegible] as well as in basalt. Nor is it con- [illegible] masses; being often as decided and distinct [illegible] the polygons being equally regular, and [illegible] the same varying number of sides. These [illegible] generally, placed at right angles to the course of the vein, extending from one wall to the [illegible] very conspicuously, in the greater Cumbray, but are also found parallel to it, and lying either horizontally, or vertically, as I have shown to be the [illegible] in Rum and in Cantyre. I need not now repeat the probable causes of the columnar structure.

The last peculiarity of configuration is the schistose, formerly discussed. This occurs both in the masses and in the veins; being occasionally combined with the columnar form, and taking place, then, either trans-

versely, or parallel to the axis of the prism. If often obscure, and limited to small portions of an amorphous mass, it sometimes occupies a considerable space, and is so distinct, that the dark-blue claystones, thus constituted, might almost be mistaken for clay-slate; though, as I formerly remarked, it is seldom perceptible but on the surfaces under the influence of the weather. It offers another point of resemblance between these rocks and lava, which is also occasionally foliated. This structure is found in basalt, in greenstone, in claystone, in syenite, in porphyry, and in hypersthene rock; and is therefore not peculiar to any individual, much less to porphyry; for which reason I have suppressed the term Porphyry slate, contrived by those who did not know a stratified from an unstratified rock, and tending to inflict their own ignorance on others. Those indications of an internal structure, discovered only on decomposition, where the weathered surfaces present a contorted, a spicular, a cavernous, a venous, a scoriform, or a botryoidal aspect, have been sufficiently noticed in the thirteenth Chapter.

With respect to decomposition, the veins are often more yielding than the surrounding strata, and thus become a frequent cause of caverns and of extended fissures: while, in other cases, being more permanent, they remain like walls, standing above the surface. Of this, and of the deep-seated decomposition both of the masses and veins, I have already had occasion to speak at some length. From this decomposition there result many varieties of soil, generally distinguished, like the volcanic ones, by their fertility. The best, however, appear to be the produce of the more recent and dark varieties; and of those, more particularly, which contain conspicuous quantities of calcareous earth As some of them also have been found to

contain carbonaceous matter, this ingredient may also assist in conferring fertility on the resulting soil.

To enumerate the geographical situations of the rocks of this division, would be an endless task, as they occur in all parts of the world. In our own islands, the western parts of Ireland, with the corresponding eastern ones of Scotland, offer one conspicuous, though scattered position for the recent traps, extending quite across the latter country. And if under much waste, and consequent separation, this trap, or these traps, bear a singular coincidence with the secondary strata, avoiding the primary, I am not so satisfied with any explanation that I might now suggest, as to trouble the reader with it. Of the older porphyries, Glenco and its vicinity, with a district near Inverary, offer the most extensive examples; since I feel very much at a loss respecting the age of those so abundant in the south of Scotland and in Northumberland. On the continent of Europe, I may enumerate the traps of the Rhine, and the porphyries of Sweden, of the south of France, of Saxony, Bohemia, and Hungary, and those of Italy in the north. They occur also between the Nile and the Red Sea, possessing historical celebrity, and in the Ural and Altai mountains. In the Andes, they are extremely conspicuous, from their continuous superiority of position; but a work which I have laboured to the utmost condensation, perhaps not very judiciously, cannot find room for details so extensive as the geography of rocks demands. Some varieties of this family, in different countries, contain metalliferous veins; but they have occurred chiefly in the older porphyries, including copper, tin, lead, and silver, principally, with, occasionally, manganese and gold.

CHAP. XXVI.

Gneiss. Compact Felspar.

Gneiss is one of the most extensive rocks in nature, and if not always the lowest of the stratified ones, as generally esteemed, it most frequently occupies that position. It presents considerable differences in its geological features and connexions; as well as a remarkable diversity of composition and structure. Under the common definition, it is limited to a foliated mixture of mica, quartz, and felspar; but this does not include all the substances which appertain to this family; whether connected together by a common geological bond, or passing into each other by variations of composition. Four divisions will include all its varieties; the essential minerals being chiefly those which form granite: and these demand a notice seldom required, in this work, respecting other rocks, from the connexion of the two leading varieties at least with its geological history.

The granitic division is distinguished by a large grain and imperfectly foliated texture, and by partial transitions into granite, from which, in detached specimens, it is often undistinguishable. It assumes this structure most perfectly when in contact with that rock; and this variety is therefore most common in the lowest positions. The schistose division alternates with and graduates into micaceous schist and into quartz rock; often in such a manner, that in describing a given district, we are at a loss what term to apply to the whole. It is small grained, with a granular texture when connected with quartz rock, and with a laminar one when with micaceous schist, and as the felspar is often al-

most undistinguishable from the quartz, except by its decomposition on the weathered surfaces; this variety is frequently confounded with one or other of the rocks above mentioned. The laminar division is more rare, and of little geological interest; being distinguished by the laminar alternating disposition of its ingredients; and the specimens often exhibiting singular combinations of colour. The last division is characterized by the presence of compact felspar. I need here only add, that the topaz rock of the Germans is merely an accidental modification of this rock; as the weissstein appears also to be, unless this be, sometimes, a granite.

The stratification of gneiss is unquestionable, however difficult it may sometimes be to determine its order, or even to perceive its existence. In Scotland, where this rock abounds, the prevailing direction of the primary strata is between the N. E. and the N. N. E.; and, while it conforms to this when obvious, there are indications in the bearings of the coast, the positions of the hills, or the comparison of parts on a greater scale, which prove, that even where most obscure, it follows the same leading line. It is often, in fact, by this prevailing conformity alone, that the stratified disposition of gneiss is perceptible; since, its irregularity is often such, and the indication of beds so obscure, that it is as easily confounded with granite by its disposition as its mineral character. It will shortly be seen, that its characters as to regularity, are connected with its peculiarities of structure; one of the leading mineral divisions being irregular, while the other equals in this respect the accompanying strata. It is superfluous to say that every possible variety of dip occurs in this, as in all the other primary strata.

The beds of gneiss are often straight, or even; or, at least, affected by no further irregularities than that

undulating deviation, both from the line of direction and the angle of the dip, which exists in all the primary strata. But this regularity prevails chiefly in the schistose variety; while the granitic one is distinguished by the frequency and extent of its flexures and contortions, generating that irregularity, just noticed, which is so characteristic of this variety and so explanatory of the theory of gneiss. These are often such, that it is impossible to assign either the dip or direction of the strata; while often producing the appearance of two sets with opposite dips, when the one is only a portion of the other, incurvated, or doubled on itself. In other cases, they are diposed in a lengthened undulating manner, either horizontally or vertically, or in larger curves resembling the waves of a sea, sometimes again interrupted by straight portions. The cliffs of the Long Island present natural sections of all these forms, detailed as in a drawing; with abundant other examples of contortions so intricate and capricious, that the imagination can scarcely exceed them.

Gneiss is so frequently traversed by veins of granite, that they may almost be esteemed characteristic of one of its varieties; while they occur in the other less conspicuously, and, in some of its connexions, only as they do in the primary strata in general. They are of all sizes, from the thickness of many hundred feet to that of less than an inch; being either simple, or ramifying, even to extreme minuteness, and interecting each other in all modes; as they also traverse the rock in transverse directions or in that of the laminæ; while, as might be expected, this last appearance prevails in the schistose variety. As I just hinted, these veins are most abundant in the granitic kind; while, being more rare in the schistose, they generally disappear altogether as its texture approaches to that of micaceous schist.

Thus also the quantity and intricacy of the contortions in any mass, are almost always proportional to the prevalence of the veins; while, when absent, the rock is never more disturbed than micaceous schist, which is but occasionally subject to this irregularity. Hence the contortions are nearly limited to the granitic variety, since it is in this that the veins abound.

In some cases, the granite veins are so abundant as nearly to exclude the original rock, so that the mass presents little else than a congeries of veins. Of the instances of this nature described in the account of the Western Isles, the most striking is that of Cape Rath. Here, the hornblende schist and gneiss are broken into pieces and entangled among the veins, as the secondary strata are in the trap of Sky, but with infinitely greater intricacy, so as to resemble a red and white veined marble with imbedded fragments of black. These do not seem to form a twentieth part of the whole mass; the progress of the different veins, and their effects in producing the disturbance, being as distinct as in an ordinary hand specimen: while it is most important in geological philosophy to remark, that the intricacy of the ramifications, and the intersection of one set of veins by a second and a third, of different textures, prove a succession of granitic eruptions at several periods; and that the absolute resemblance of the whole to the parallel cases of trap veins successively intruding among strata, can leave no question in the mind of any man capable of seeing and reasoning, that there is but one theory for granite and for trap. He who declares his doubts, in such a case, is the suicidal betrayer of his own calibre of mind. The appearances are, in fact not merely similar or analogous, but identical.

The last cirsumstance of importance as to these veins is, that they do not exist where gneiss alternates

with extensive strata of clay-slate, quartz rock, or micaceous schist; and this leads me to enquire into the philosophy of the appearances in question. They who have called these veins contemporaneous, are of those who write phrases without ideas; and they who have supposed them independent of granitic connected masses, have wanted industry or capacity to examine them. I have traced these veins to their parent masses wherever a mass existed; and where they cannot thus be followed, it is because the fundamental granite is out of sight and reach. If the universal inference is not safe, it may be asked what and whence is a granite vein. Let me also remark, that in numerous parts of Scotland, where the leading masses of gneiss are schistose, evenly stratified, and scarcely ever traversed by granite veins, they become contorted and irregular as they approach the granite; assuming also the granitic character, and becoming intersected by veins, numerous in proportion to the vicinity of the mass. The conclusion is almost too obvious to require being stated; and it implies the most essential part of the theory of gneiss. The fluid granite has invaded the aqueous stratum as far as its influence could reach, and, thus far, has filled it with veins, disturbed its regularity, and generated in it a new mineral character, often absolutely confounded with its own. And if the more remote beds, and those alternating with other rocks, are not thus affected, it is not only that it has acted less on those, but that if it had equally affected them, they never could have existed, or would have been all granitic and venous gneiss. Thus are its varieties of character, even to its absolute transition into granite, explained.

Though the general facts have formerly been stated, it is necessary to mention, as part of the history of

ntortions
the pre-
e rock is
which is
Hence the
c variety,

ndant as
the mass
Of the
nt of the
ape Rath.
oken into
secondary
ly greater
ite veined
These do
ole mass;
effects in
t as in an
important
e intricacy
one set of
textures,
several pe-
the whole
intruding
ind of any
here is but
ho declares
ayer of his
in fact not

s to these
alternates

this rock, that the appearances of these veins indicate their forcible intrusion into the gneiss, and that it has yielded to them under a softened state. This is proved by the connexion between the contortions and the veins, by the intrusion of parallel veins among the laminæ, and by the curvature of these, in a direction corresponding to the motion of the fluid, which has often also insinuated itself just within the displaced edge and no further: the whole marking plainly the forcible fracture of the rock and a simultaneous intrusion of the substance filling the fissure. One fact alone, like this, is demonstrative; because although many veins might possibly be formed in some other imaginary manner, such a one as this could not be the consequence of any other action. The case of parallel veins is explained by the preferable facility with which the schistose variety yielded in the direction of its laminæ; while the condition of the granitic kind excluded all such tendency. If it is yet necessary to produce facts in proof of this intrusion, the same granite veins which traverse a gneiss, in Tirey, traverse an included limestone also; both of them being contorted and displaced, and the chemical composition of the latter materially altered. It is evident that both rocks existed before the passage of the veins; while, although the resemblance of gneiss and granite might console those who consider the veins of the latter as modifications of the former, the same cannot hold good respecting limestone. A similar occurrence in serpentine, in Scalpa, is merely a repetition of the same argument; and I need not now enumerate the endless examples of mechanical disposition which prove the same inference.

In proceeding to enquire respecting the strata with which gneiss alternates, there is a difficulty, arising

chiefly from the use of this term as indicating a geological series, and as the mere name of a rock. If it be used to express the latter alone, gneiss alternates with many other strata, sometimes much inferior in quantity, to which the arbitrary and abused term *subordinate*, has then been applied; yet equally alternating with the same rocks, and on an extensive scale, in such a manner, that so far from including them it is itself inferior in quantity, and might, with equal reason, be considered subordinate. But all this difficulty, like most of the other vexations of Geology, are the produce of systems, themselves the produce of original ignorance, promulgated and enforced by equivalent minds, so as to enslave other similar ones; as has happened in every science, from logic and metaphysics to mechanical science and medicine. It is the hypothesis of the *formations* in the secondary strata, in another form; meaning nothing when it cannot prove some fact in the history of the Earth, yet not simply foolish and innocent when it becomes a substitute for true description, because conferring the mischievous authority of a philosopher on a mere phraseologist. There is but one reasonable and philosophical view in the present case. If there are alternating beds of other rocks which have undergone common changes of flexure and contortion with gneiss, that whole series was completed before this subsequent influence and change: where this does not occur, the deposits may have been of different and distant dates, especially where large masses of other strata intervene; though the limited influence of the granite may render even this doubtful. In any case, the term subordinate is as idle as all the other Germanic philosophy which continues to obstruct the progress of this science.

The most common substance in the series of contorted gneiss, is hornblende schist, which even seems essential to the granitic varieties containing hornblende, since it is never absent; while if it also occurs in others, it is rarely or ever in the same abundance. Occasionally indeed, the hornblende schist so far exceeds the gneiss in quantity, that this latter might be held the subordinate rock. Analogous to this is actinolite schist, differing from it only in the slight distinction which exists between the two minerals, but, comparatively, of very rare occurrence. In a similar manner, there are found beds of micaceous schist; though it is sometimes difficult to distinguish the schistose gneiss from this rock. The distinction is obvious when it occurs among the granitic varieties; though this is rather a rare incident. If chlorite schist also occurs in the same manner, the analogy of these rocks is such that I need not dwell on it. Limestone is sometimes also found included in the gneiss series, in limited flat beds, and in large irregular concretions, or immense nodules. Beds of quartz are equally rare; being sometimes simple, at others, interspersed with irregular crystals of felspar; while often so circumstanced that it is difficult to determine whether they are beds or veins. A granitic compound, without any marks of foliation, resembling some of the syenites of the trap family, and consisting of an uniform mixture of quartz and felspar interspersed with acicular crystals of hornblende, also occurs in Sky and in other places, yet rarely. If it is probable that many other peculiar occasional compounds occur in the same situations, as yet unnoticed, I shall point out but one more, from having perceived that they are sources of difficulty to students, or else induce them to suppose that they had discovered a new rock in the general

system, as the Germans have thus intruded their topaz rock and their weissstein into it. This is a compound of hornblende and garnet; the structure being small spheroidal, and the whole analysis extremely difficult. It occurs in Guernsey and Sark.

I must lastly notice the granite which occurs in an apparently regular stratification with gneiss, and which has aided in giving rise to the opinion that granite was a stratified rock. It is sufficiently easy to distinguish these beds from conformable veins; and they are then true portions of the gneiss, as much stratified as the rock in which they are contained. They occur only in the granitic varieties, and pass by gradation into the surrounding foliated rock. As far as I have observed, they rarely exceed a few feet in thickness, often not many inches; but may probably be found of much greater dimensions. Even then, they would not prove the stratification of granite, which possesses characters not to be mistaken; while, on considering the near approach to a purely granitic stratum which gneiss so often undergoes, it can excite no surprise to find the foliated disposition occasionally disappear.

The association of gneiss with other independent rocks, in the order of precedence or succession, forms that part of its geological history which, from the prevalence of an erroneous theory, is most in need of illustration. It has been said to follow necessarily in order after granite; but it will be seen that it succeeds almost every one of the primary rocks, and may consequently be followed by any one of the series, and even by the secondary strata. If, in many parts of Scotland, it does occur in this manner, it is not, in those places, the sole rock which immediately follows that one; so that the correlative rule, which would exclude every other stratum from that position, is false, as has been shown in the last chapter. Its alternations with mi-

caceous schist and with quartz rock, are equally abundant and obvious in Scotland, especially where it is about to be finally succeeded by either of those; and they are the source of great difficulty in attempting to note the respective boundaries in a geological map. It is not that a few beds alone occur before the final termination of the gneiss; since the alternations extend over considerable tracts of country, in Sutherland, and in Perthshire. In these cases, it is the schistose variety which is present; while there is not only an alternation, but a transition from the one rock to the other two, as is easily understood from the similarity of their mineral composition. Nor is there any reason in the general theory of the composition of rocks, as formerly laid down, why these alternations should not happen. It is thus easy to see how geologists may give different reports on a country of this nature, even when unbiassed by hypotheses. They who may see chiefly the beds of gneiss, will consider the other rocks as subordinate, and describe the country as a tract of that substance; while the reverse will happen where the principal attention has been given to the associated rocks. Yet the one has no further title to be considered as the principal formation than the others; and it will be always the safest practice to describe the simple facts, rather than to incur the hazard of errors by general statements. Under great minuteness and frequency of the alternations, it is in vain to be anxious about distinctions where Nature has made none; and we must be contented to admit on the large scale, what we so often find on the small one. That which ought to be, is the eternal obstacle to the discovery of that which is.

In numerous parts of Scotland, the gneiss is immediately succeeded by argillaceous schist, exhibiting the usual intermixture of fine and coarse strata. In Iona, the schist is interposed between the granite and the

gneiss, and, in Isla, it alternates with the gneiss, or forms beds, in a series or mass, in which itself is the predominant rock. In many parts of Perthshire, the gneiss often alternates with beds of limestone, too considerable to be reckoned subordinate to it; since, in some of the examples, they extend for twenty miles, with scarcely an interruption. I have elsewhere shown that it alternates also with the primary red sandstone. If gneiss thus succeeds to every primary stratum, so, in Sutherland and Shetland, it is immediately followed by the old red sandstone, and, in Morven, by the lias and subsequent strata containing coal, forming the brief geological series formerly quoted. I may lastly remark, that the gradation of gneiss into chlorite schist, and ultimately into the red sandstone, in Sky, is not less interesting than those into quartz rock and micaceous schist; and that its whole history, as now given, may serve to prove under how little knowledge geologists have hitherto been establishing canons for the order and relations of the primary strata.

From former general enquiries, and from the present history, the theory of gneiss ought now to be apparent.

Nature, our guide where direct experiments fail, teaches us, that, from the most recent bed of sand or clay, through the whole series downwards, there is no chasm among the stratified rocks to mark where a mechanical deposit ends, and one of a mixed character begins; as, from this to the most perfect crystalline stratum, there is an equal absence of all decisive marks of the cessation of one process and the exclusive reign of another. We also find that approximate beds often exhibit a disposition purely chemical, alternating with one partly or purely mechanical; and that, even in the same rock, a given bed will present an instance of both characters in association. Hence, the mineral composition of gneiss presents no argument against its

original deposition from water; a supposition confirmed by its common prolonged and parallel direction with the other strata. It has not yet indeed presented any decided marks of that mechanical arrangement which so often occurs in other stratified rocks; since I must explain the parallelism of the mica, which has been supposed a proof of such arrangement, in a very different way. In hypersthene rock, an unstratified member of the trap family, the crystals of that mineral often occur in a similar laminar manner, so as to communicate a fissile tendency to it. And in Kerrera, mica itself is thus found, not only in a mass of trap, but in a vein of the same substance, with the same parallelism to the sides of the vein as it has to the plane of the stratum in micaceous schist; while a similar disposition of mica and pinite both, is common in veins of porphyry. This cannot have resulted from mechanical subsidence; it must be considered as the result of that common polarity by which the distinct crystals in a common mass are so often regulated. And it has already appeared, that as granite is the produce of fusion, the same law may be extended to the granitic gneiss; while the form of stratification has been preserved under those circumstances, as in the stratified traps, and in the siliceous schists by which they are occasionally accompanied. Diminishing influences of heat will account for the several other varieties of this rock, as they do for the different primary strata: while it is almost a repetition to suggest why such actions should have induced the chemical changes found in some of the most distinctly stratified varieties, why greater chemical changes should be accompanied by a more obscure stratification, ending in the final passage to granite, why the proximity of this rock is so generally accompanied by gradations between the *two,* and why, wherever granite veins abound, the in-

vaded gneiss is not only disturbed, but assume these character of the accompanying granite. If exceptions occur, they depend, like all others, on collateral circumstances generally easy of explanation, but requiring a particular one for each case. I need only further repeat, that the alternations of gneiss and hornblende schist present a very exact analogy to those of sandstone and shale; while as the latter are converted into hornblende schist and basalt by the action of heat, it is easy to see how the whole compound series of gneiss should be connected with the same cause.

Hitherto, I know not that any decided fragments have been found in gneiss; although the occasional occurrence of nodules of hornblende and quartz, round which the laminæ of the gneiss are incurvated, may perhaps be supposed to bespeak a mechanical origin for these. In Scotland, beds of a fractured and conglomerated gneiss are sometimes found adhering to the surface of the ordinary rock; a circumstance which has been considered remarkable by Von Buch and other geologists; without reason, since it is a fact of no peculiar interest. It is evidently the lowest portion of the red sandstone series; as noted under that head.

The great features of gneiss, as they affect the peculiar form and outline of a country, offer almost every possible variety. In the Uists, Tirey, and Benbecula, and far more conspicuously in Sweden, it often presents a dead level extending over a surface of many square miles; in some places, without a single protuberance from which the subjacent rock could be conjectured; while in the same islands, and elsewhere, the surface becomes slightly undulated, with naked protuberant masses, which, increasing in numbers, confer a very singular character on Rona and Coll, and on some parts of Sutherland. In these places,

thousands of irregular and naked rocky eminences, of various elevations, cover the surface; separated indeed by intervals of herbage, and by stagnant pools, yet so that a distant prospect presents the appearance of one continued pavement of solid stone. Where the elevation of the ground increases, the prevailing features of the country resemble the granite ridge of Dartmoor and Cornwall; the hills, further, gradually assuming a mountainous character, while the outline still continues tame and rounded, with few projecting rocks or precipitous faces. At length, without any material increase of elevation, the mountains of gneiss start up into craggy and abrupt summits, as in Sutherland, in Invernessshire, and elsewhere: the district of Knoydart forming one of the wildest tracts in all Scotland, and combining more varied forms of grandeur than any part of the western coast.

The relative effects of the two leading divisions of gneiss on the soil and produce of the country, is also worthy of notice. Where the schistose variety prevails, the character of the soil is equal or superior to that which is the produce of micaceous schist. Where the granitic variety occurs, it generally resists the ordinary disintegrating powers; whence that peculiar nakedness of the surface already mentioned. Considering the close resemblance between this rock and granite, the reasons are not obvious; further than as it may depend on the absence of fissures, denying access to water, and to consequent frost. Hence also arises that absence of soil so remarkable in most of the Scottish gneiss islands, though no general rule can be derived from this fact: as, in many other countries, even the granitic gneiss decomposes as readily as some granites, forming a deep and rich soil; as in Guernsey, and also in

Aberdeenshire, remarkable for the destruction of all its rocks, and for the great consequent depth of its untransported alluvia. Though the indestructibility of the granitic varieties of gneiss points it out as adapted to the purposes of architecture, the difficulty of shaping it almost precludes its application to building. But, in the micaceous varieties, this objection does not hold; while considerable labour is saved by the possession of, at least, two natural parallel surfaces. When fissile, it thus also becomes fit for roofing; particularly in those mountainous districts where slates of ordinary weight are unable to preserve their places.

In Scotland, it contains metallic veins, producing lead and copper, and, rarely, plumbago: as it includes tin, on the continent of Europe; where it appears to abound more in metalliferous veins than in this country. It there also produces copper, silver, antimony, zinc, wolfram, lead, molybdena, and gold; but the last two substances, in particular, are rare.

Compact Felspar.

That compact felspar which occurs among the porphyritic and trap rocks, forming the basis of porphyries, is well known to geologists. But I cannot discover that a similar, if not the same mineral, has been observed as a member of the primary strata, unconnected with any masses of porphyry, or of the other intruding rocks. It is therefore a new rock in the system, in addition to all the others which I have introduced; while the reasons for associating it in the same chapter with gneiss, will be apparent.

The term compact felspar is here therefore understood to mean a stratified rock, if not always very regularly so, forming a member of the primary strata,

and consisting, chiefly, of that mineral, sufficiently known by mineralogical descriptions. If most frequently simple, it sometimes also contains interspersed particles of quartz and hornblende; and, by the increase of these, it passes into some of the varieties of gneiss.

In some places it seems scarcely stratified; forming, rather, irregular nodules like those of limestone and serpentine; and no further therefore a source of trouble or doubt. As Iona offers a convenient example of this form, I may refer to that island for such further information as cannot easily be given in words, as well as for the evidence of the fact itself. In the Long Island and Rossshire, it is stratified, at least as distinctly as the gneiss which it accompanies; and it may thus also be seen and studied in the neighbourhood of Pol Ewe and Loch Greinord, and on the shores of Loch Maree.

With some very trifling exceptions, in which it is particularly connected with granite, it seems exclusively to be associated with gneiss, whether as an imbedded mass, or an alternating stratum. Such gneiss is remarkable for containing compact felspar as an ingredient; and the two rocks pass into each other by a mutual gradation; the one acquiring, or the other losing, those ingredients on which the distinction depends. It must still be added to its geological characters, that it is found also in the form of veins in the same situations, frequently ramifying into filaments of extreme tenuity. On decomposition, this rock forms a very fine porcelain clay; and may thus become an object of research when better known.

If it shall appear to Geologists that a new rock has been unwarrantably added to the System, some other mode must be discovered of classing a substance which cannot be considered a mere mineral, and which refuses to associate with any other rock.

CHAP. XXVII.

Micaceous Schist. Chlorite Schist. Talcose Schist.

Though I have placed Micaceous schist next to gneiss, in conformity to the general opinions respecting its order in nature, it has already appeared, and will soon be still more evident, that this order is not constant. If a definition of so familiar a rock is nearly superfluous, it is needful to say, that it ranges between mica and quartz, so that as the examples on one side consist of little else than condensed mica, the others pass into quartz rock by an imperceptible gradation; as is common especially at the mutual boundaries of these two deposits. The varieties must be sought in the Classification of Rocks; yet I must note here, as essential to its theory, that it occasionally contains fragments, or portions of a conglomerate.

In this island, micaceous schist is limited to mountainous districts; the features which it confers on the country being various, and often picturesque. In some tracts, the hills are tame and undulating, like those of argillaceous schist; ranging from 500 to 1000 feet in height, and rarely broken by projecting rocks, whence they gradually rise to upwards of 4000 as in Ben Lawers; acquiring more striking characters, and displaying abrupt precipices, with summits occasionally serrated, and partially covered with vegetation. As this rock often presents considerable fissures, and, while mouldering more readily than gneiss, is favourable to vegetation, the lower cliffs and precipices are often covered with trees, producing a variety of picturesque scenery well known in the vicinity of Loch Cateran. In Scotland, as elsewhere, it occupies extensive tracts, unmixed with any other rock, but oc-

curs also in very limited beds, alternating with other strata, as a portion of some complicated series; while, further, it occasionally intrudes as an incidental substance, where the predominant series belongs to another family.

It is found in contact with granite in Arran; forming a mass of considerable dimensions, and, allowing for its insular position, connected with the most extensive range of the same rock in Scotland. The granite which ranges from Appin to Rannoch, is also often covered, on its southern boundary, by micaceous schist, occasionally intermixed with quartz rock and argillaceous schist; this contact being the northern margin of that great tract, the southern limit of which reaches to the shores of the Clyde. Extensive examples of the same junction occur also in Perthshire, in Sutherland, in Aberdeenshire, and in Shetland. It is interesting to remark, that where thus in contact with granite, it often assumes the character of gneiss for a small space, by acquiring felspar; but this change is always limited to a short distance from the contact, or to the portions traversed by the granitic veins. The fragments entangled in the granite are also often converted into the same substance; under an obvious analogy to the change from argillaceous to micaceous and hornblende schists in the same circumstances.

As already remarked, micaceous schist succeeds to gneiss through a very considerable part of Scotland; alternating with it by such frequent interchanges, that the limits cannot be accurately defined, and forming also occasional beds within it. I have also shown that it does not necessarily follow this rock: which is succeeded, in at least an equal degree, by many others of the primary strata. As it is intimately

connected with quartz rock, by its ingredients and by its structure, so it is often united to it in geological position; either preceding or following, as far as succession or precedence can be determined respecting those primary strata which, occupying high positions, are sometimes reversed on different sides of the perpendicular. It also alternates with that rock in equal and smaller beds, so that a given tract or mass cannot be preferably referred to either; while, further, it forms occasional beds in the larger masses, or else graduates into it in an imperceptible manner. As might be expected, it alternates with the primary limestones, since these occur in every situation among the primary strata. I know not that extensive masses of this rock have yet been found succeeding to equally extensive ones of the argillaceous schists, and in contact; but, in Isla, considerable bodies of the latter are found beneath the micaceous schist, though separated from it by intervening beds of quartz rock. Lastly, as a deposit independent of other rocks, or only partially intermingled with them, it is intimately associated with chlorite schist, and occasionally with talcose schist, as will immediately appear.

Besides these connexions on the great scale, it is associated with many different substances, in smaller quantity and in frequent alternations. In the chain of Isla, it thus alternates, in repeated beds, with quartz rock, clay-slate, and graywacke of various characters; these alternations being extremely numerous, and the space occupied by the micaceous schist often very minute, as again noticed under Argillaceous schist; and it will be seen, under Chlorite schist, that it thus also enters into another series of which that rock and hornblende schist form the most remarkable portions. From this history of its alternations, may be

deduced its relations to the primary strata: but I must also add, that it is often immediately succeeded by the secondary, as in Cantyre.

Micaceous schist, like all the primary strata, is disposed in beds; often, however, rendered obscure by their great thickness, by the want of distinct seams of division, and by the irregularities and contortions to which this rock is subject. When it enters in small quantity among other rocks, the beds are, however, always very distinct; and, in the Chlorite series, extremely regular and even. Its interior structure is various; sometimes consisting of straight laminæ, rigidly parallel, and in one plane; while at others, the general parallelism of the laminæ is maintained, but their thickness varies, so as to affect this appearance of regularity. In other cases again, these are minutely, or even largely undulated, still preserving the disposition in a plane; until, by at length increasing in size, they also lose that general conformity to an imaginary plane, finally assuming the most capricious contortions; no longer bending round any given straight line or set of parallel lines, but presenting curvatures in every possible direction. From the frequent difficulty of discovering the true position and limits of the bed, it is thus sometimes impossible to know whether these curvatures involve the whole stratum, or whether they affect the interior structure only. The lesser undulations and curvatures, are, evidently, often independent of any corresponding change in the evenness of the bed; and the same probably often holds true of the more complicated, since they do not seem to pervade the whole mass, but rather to occupy particular spots among the neighbouring and less disturbed laminæ. In some of these cases, it is very difficult to trace the stratified disposition; and such a state of

things will often be found to prevail over considerable tracts of country; while, in the immediate vicinity, the beds are in their naturally straight order. These curvatures, or contortions, must often exist where they cannot be seen; because the same set of beds, traced on their prolonged edges, frequently present reversed dips at the two extremities; as happens on a very large scale in Cantyre. I may lastly remark, that although granite veins traverse this rock in common with others, they do not abound in it as in gneiss, for reasons which must now be apparent. The veins of quartz, so common, often follow the flexures of the rock itself, proving that they have been capable of flexure, themselves; while it is difficult to decide whether they have been, in all cases, the produce of aqueous infiltration.

I have found considerable difficulty in satisfying myself respecting the cause of the laminar disposition in this rock. In many cases, and particularly in the minute alternating strata, there is unquestionable evidence that it is parallel to the plane of the bed, with certain minute exceptions, arising from the undulations of the laminæ, equally occurring in argillaceous schist, and even in secondary sandstone. In these, the schistose structure, or the laminar tendency, bears no necessary relation to the plane of the bed; and the same might therefore be imagined of micaceous schist. But in schistose gneiss, to which this rock bears a much nearer affinity, these are always coincident: so that the same rule probably holds in this one also, though not necessarily in all cases; since, in the argillaceous schists, the laminar structure is sometimes parallel, while, at others, it occupies different angles with regard to the plane of the stratum. With respect to the undulations and contortions of these, it is

to repeat former general doctrines to say, that they have been produced by mechanical force when the rock was in a soft state; yet under conditions so varied, that while, in some instances, it has undergone the most intricate contortions, in others it has not yielded without fracture. Whether this effect was here produced by one or other of the conditions formerly examined, namely, by the effect of heat, or in consequence of the presence of water at a certain stage of its existence, is a question that needs not be discussed again.

To conclude the theory of this rock, it has been disputed whether micaceous schist was a purely crystallized and chemical compound, or whether it was of a mechanical origin. As already remarked in the case of gneiss, the disposition of the mica is not a proof of the latter; but the regular order of the beds, implying a subsidence from water, indicates in this, as in other rocks, an originally mechanical arrangement; as is completely proved by its alternating with conglomerated substances, such as the coarse graywackes and the quartz breccias which accompany it in Jura and Scarba, and still more, by its containing conglomerate portions, including fragments of granite, limestone, quartz, and other rocks, as I originally pointed out in Isla, Schihallien, and Fetlar in Shetland. But the proofs of a chemical structure combined with a mechanical disposition, are not less perfect; while I need scarcely repeat that this occurs in rocks which evince undisputed marks of mechanical structure, by containing organic remains. To such chemical causes must be referred those crystallized substances, such as garnet, which so often form a constituent part of the rock, and which have unquestionably been produced in the places where they now

exist. These are of igneous origin, as will be perceived by turning to the nineteenth Chapter; and, as formerly suggested, we must here consider, that after the deposition of these strata, they were subjected to that degree of heat which permitted the minerals to crystallize; as they do, in similar circumstances, in the volcanic rocks.

As the composition and texture of micaceous schist are infinitely various, no general statement will include the different effects which follow its decomposition. Hence the varying appearance of the mountains which occupy the great belt that reaches from the Mull of Cantyre to near Stonehaven; and thence the characters of the soils are equally various. In some places it is a deep and fertile yellow clay, from the prevalence of mica in the rock, while, in others, when the proportion of quartz is large, a barren and thin sandy covering separates the brown peat from the solid rock.

Its œconomical uses are very limited, from the irregular nature of its fracture, though the tender varieties are sufficiently tractable for use; while, it is often a substitute for slate, well calculated to resist the winds of a boisterous region. A sculptor might be surprised to see it applied to his own art; yet the cross of Campbelltown and those of Iona, ornamented with Runic knots and foliages, present an intricacy of design exceeded only by the precision and durability of the workmanship. If it is esteemed, on the continent of Europe, as a material for lining furnaces, that can only be true of those varieties which contain a large proportion of quartz; as it is fusible in a very moderate heat, where the mica abounds. Metalliferous veins occur in micaceous schist; containing iron, arsenic, lead, zinc, cobalt, and, rarely, gold. The mine

of Tyndrum holds an ambiguous place between this and quartz rock, producing zinc and lead; and, in other places in Scotland, it contains lead and copper.

Chlorite Schist.

Although this does not, like micaceous schist, appear to form large tracts of country, or alone to constitute mountain masses, it is far too important to be classed as a variety of that rock. That it has not found a place in former geological arrangements, is no reason for excluding it from the present.

Its frequent connexion with micaceous schist, together with its analogy in structure and composition, render this its natural place; yet it will be found to possess a much greater variety, under that principle of arrangement by which I have classed, under one title, all those hitherto unnamed rocks, which are associated by geological position, by the existence of a predominant or characteristic mineral, and by a frequent transition into each other. The details of these will be found in the Classification of Rocks; while, respecting its general definition, it is that of micaceous schist, substituting foliated chlorite for mica. The description of the great features of micaceous schist, apply equally to this rock, as far as it is known to me; since they most commonly occur together, either in a simple association, or in alternation with others. Where intermingled, in minute and frequent alternations, with other strata, it can confer no peculiar features on the aspect of a country.

Chlorite schist is best known as accompanying micaceous schist; forming, in this case, irregular beds, of greater or less extent, sometimes alternating with that rock, but more frequently graduating into it, so that the limits are undefinable. Thus it is often im-

possible to decide under what head a particular tract should be ranked; while the cause of this will be apparent, by recollecting that quartz is common to both, and that the boundary between foliated chlorite and mica is evanescent. To make any remarks on the dimensions, forms, and positions, of its beds, as it occurs in these situations, would only be to repeat the history of micaceous schist.

The next association in which it occurs, is as an integrant part of a peculiar series, as yet unnoticed by other geologists, which, in the Description of the Western Islands, I have termed the Chlorite series, occupying a considerable uninterrupted space from Cantyre northwards; and succeeding to the micaceous schist by an undefinable gradation. At first, a bed of the chlorite series occurs here and there in the latter rock, till, encreasing in frequency, they become predominant; while the micaceous schist gradually diminishes so as to be no longer perceptible, except on close examination. During the progress of this change, the stratification, which was so confused as to be scarcely distinguishable, becomes gradually so even and regular as to put on the appearance of a series of secondary strata. The deception is much aided by the thinness of the beds, more especially by that of the quartz rock and micaceous schist. This contrast of character is one of the most remarkable features in this series, as distinguished from micaceous schist; the latter rock being generally confused, and with difficulty distinguishable into strata; while the former, even in its vicinity, maintains an invariable regularity throughout its whole extent. The resemblance to the secondary strata is also much assisted by the perpetual interchange and repetition of the different substances in this series; each individual being suc-

ceeded by some other, and no stratum occupying more than a few feet, while many do not exceed two or three inches in thickness.

The leading strata which give the character to the whole series, are the following, placed as nearly as possible with a regard to their relative importance, or to the spaces which they respectively occupy. The first is a schist, thickly and imperfectly fissile, consisting of schistose chlorite and felspar alone, or of these minerals with hornblende or with actinolite superadded. By the increase of the actinolite or of the hornblende, this stratum becomes so compact as scarcely to be distinguished from a hornblende or an actinolite schist; into which it seems ultimately to pass. Quartz rock is next in quantity, varying much, both in its colour and texture, so as to present its usual modifications when in an independent situation. Next in order is scaly chlorite schist, arenaceous, or silky, and either flat or minutely undulated, splitting into thin laminæ, and generally tender where exposed. Micaceous schist forms the last of the essential beds of this series; being always flat and fissile, and frequently presenting a greenish hue, so as at length to pass into the preceding rock. These two last beds rarely exceed a few inches in thickness, and do not together seem to occupy a twentieth part of the whole; while, in some places, the simple hornblende schist predominates over the compound chlorite schist, almost usurping its place in the series. The usual order of arrangement is that of a repeated alternation of every member; but the micaceous schist is generally next to the quartz rock, and the thin chlorite schist accompanies the thick and compound variety. Thus the contrast between beds of different dimensions, with the perpetual interchange of colour and

the extreme regularity of the strata, renders the whole very conspicuous, and strongly distinguished from the shapeless and contorted beds of micaceous schist. The various alternating substances, of more rare occurrence and of a subordinate character, will be found in the Classification of Rocks.

As the next series in which Chlorite schist forms a member, is described under Argillaceous schist, I need here only say, that the predominant substances in it are micaceous schist, clay-slate, and graywacke. It occurs here under numerous aspects; many of the varieties resembling in structure the accompanying graywackes, and differing only in the substitution of scaly chlorite for indurated clay; while it here also presents transitions into clay-slate. And, in the last place, it is found, though rarely, accompanying gneiss: immediately following, and, further, alternating with that rock; while a gradation between the two also occurs, producing varieties which may be ranked under either, as they tend most to the one or the other. This was already indicated under Gneiss.

In compliance with the custom of geologists, I have here noticed the metalliferous reputation of the rocks described, though I know not that any useful information is conveyed by this popular usage. As a question of theory, there is assuredly none; since we know of no necessary connexion between any rock and the metallic veins which it may contain; while, in practice, it appears equally fruitless; since the same rock, in one country, abounds in metallic veins, when, in another, it is utterly barren. Whether chlorite schist is to be ranked among metalliferous strata in foreign countries, remains to be known; as it has been very imperfectly described. But as the barrenness of Scotland in metals is notorious, their absence from our

own chlorite schist is no rule for others; though I may observe, that in Ben Lawers, it abounds in Titanite, where it is traversed by quartz veins. Its other uses may be compared with those of micaceous schist: being quarried for roofing slate in Argyllshire, though inferior even to the worst varieties of argillaceous schist.

Talcose Schist.

If Talc be substituted for mica or chlorite, the definition of talcose schist is the same as that of the preceding two; but as it occasionally graduates into both, it cannot always be decidedly distinguished from them. As far as I have observed, it is always very limited in quantity, and of comparatively rare occurrence. Resembling micaceous schist in its general aspect, it is disposed in similar irregular beds where it occurs, but is as yet only known to me as forming portions of the general masses of gneiss, chlorite schist, or micaceous schist, or as being peculiarly connected with Serpentine.

Where in company with gneiss, it is commonly attended by chlorite or micaceous schist, or both, forming a sort of intermedium by which it is connected with the principal rock. The strata are, generally, exceedingly limited in all their dimensions; and if occasionally thick in some parts, yet they become soon extenuated till they disappear. Where associated with micaceous or chlorite schist, it passes into both of these by imperceptible gradations; as might be expected from the affinity existing among the three minerals respectively characteristic of these different rocks. In these situations also it is always in very small quantity; at times indeed so very minute, as to occupy only an occasional lamina in the general mass. Even then, its natural affinity to serpentine

is indicated by the presence of steatite, foliated talc, and asbestos. As accompanying that rock, it generally forms the boundary between it and the schistose strata in which it happens to lie; seeming to be abundant only when they consist of micaceous schist. When the including rock is gneiss, it often unites with that, so as to form a talcose gneiss, noticed in the Classification. I know not that it occurs conspicuously in argillaceous schist; but minute laminæ of it are occasionally found, producing that talcose surface which this sometimes presents on splitting.

This rock is the repository of many well-known minerals; but if too limited to be largely metalliferous, it contains Chromat of Iron in Shetland. As a building stone, its harder varieties have been advantageously used in Scotland; while the facility of shaping it, and its apparent indestructibility, entitle it to the notice of architects. Though recommended for furnaces, it has always proved to be very fusible in my own trials. Because sometimes used for vessels, it has been called potstone; to the no small confusion of the nomenclature, among careless mineralogists.

CHAP. XXVIII.

Hornblende Schist. Actinolite Schist.

The term Hornblende schist implies a familiar stratified rock, of which it is a sufficient definition to say, that it consists of hornblende, alone, or intermixed with felspar, common, or compact; while generally, if not invariably, schistose. Thus it may resemble the greenstone of Trap, in specimens; while the chlorite series just described contains some compact beds of it, often remarkable for a prismatic structure, and thus capable of deceiving even a good observer. But in every other case, nothing but extreme ignorance or prejudice can confound hornblende schist with an unstratified rock: while the terms primitive greenstone and greenstone slate, here suppressed, have produced utter confusion, in this case, in the hands of those who have so widely perverted all geological philosophy: confounding, not merely the schistose concretionary traps with this rock, but all the traps of apparently antient associations, with a stratified substance.

Hornblende schist is so rarely found, in this country at least, independent, and occupying a distinct place, that little can be said respecting its great external features. The only example which has occurred to me, is the mountain Ben Lair in Rossshire, which consists almost entirely of this substance, surrounded by gneiss. It rises to the height of 3000 feet or upwards; displaying a very rugged and picturesque surface, with extensive faces of bare rock. In all other situations, hornblende schist either forms a portion of the great mass of gneiss, or alternates with the other primary schists; so that the general aspect of the country is determined by a variety of concurring circumstances.

Like the other primary strata, it occurs in distinct

beds of various dimensions, and under all the usual variations. When intermixed with gneiss, which is its predominant association, for reasons already apparent, it follows the contortions of that rock; affording, by its contrast of colour, the most perfect indications of those: and, as already remarked, it is traversed by the same granite veins. Hence, it has been called subordinate; but, as already said, this only proves that the intrusion of the veins was posterior to the deposition of the compound mass. Wherever, like the gneiss itself, it is unaffected by these veins, all that follows is, that no intrusion of granite has there taken place since its deposition. It is occasionally found among the greater masses of micaceous schist; while hornblende then sometimes enters into the composition of that rock, so as to produce an intermediate substance. In these cases, other compound and anomalous strata are often present; chlorite schist being frequently among the number. Its peculiar association with this rock has just been described.

It is occasionally found accompanying argillaceous schist; appearing to pass into the finer clay-slate by an insensible gradation. I have already shown the peculiar interest attached to this transition at the contact with granite; particularly remarkable where its veins traverse clay-slate, or whese fragments of the latter are entangled in it. From this fact, and the parallel ones at the contact of shales and trap, it would appear, that the fusion of clay-slate, whether primary or secondary, is, under various circumstances, capable of generating, either the common trap rocks, or the hornblende schists: nor is it perhaps difficult to explain, by a more gradual cooling, and consequently, a slower crystallization, the particular causes which may have determined the latter rather than the former effect. Instructive examples of this transition occur

in Isla and in Iona, where there is a gneiss containing clay-slate as an ingredient, while other portions of the same beds include schistose hornblende and I have also traced the steps by which the one graduates into the other. On the skirts of Cruachan, where the argillaceous strata are penetrated by granite veins, there is a perfect gradation into hornblende schist, at the contact; while the entangled fragments consist of this latter substance, evidently produced by a change of the character of the former. And near Busta in Shetland, the same occurs on a much more extensive scale; some of the argillaceous strata being converted into hornblende schist, and others into siliceous schist; while, under peculiar circumstances, a species of gneiss, resembling that of Isla and Iona, is produced. These facts require no comment; but the latter are particularly important, because the whole gradation between the three substances can be traced: the simple argillaceous schist being first indurated to the state of siliceous schist, and finally, as if by a greater degree of the same influence, crystallized. Thus also we can explain how the disposition in strata is united to the chemical texture of the rock in question. To say more on the origin of this substance, would be mere repetition: especially after the recent discussion respecting it. The resemblance between actinolite and hornblende is so great, that it is almost superfluous to mention the change of this rock into actinolite schist. And I have only finally to add, that it incidentally accompanies limestone; the calcareous bed being then generally intermixed with crystals of hornblende, as near Loch Laggan and in Ben y Gloe.

I formerly noticed the probable remains of shells which I have found in this rock, and am not aware that it is the repository of any metallic minerals. As a building stone, it deserves a regard which it has not yet

experienced; from the facility with which it is squared by the hammer alone, as well as from its strength and durability. It is also among the best of paving stones.

Actinolite Schist.

While mineralogists shall distinguish actinolite from hornblende, this rock must be separated from hornblende schist; and I am thence bound to notice it, though its geological history is but the same. Substituting actinolite for hornblende, the definition is given; and if, when simple, it varies according to the magnitude, form, and interlacement, of the crystals, so, when compounded, the analogy is equally perfect, though varieties also occur, containing mica, talc, chlorite, and hornblende.

The Geological information respecting it is so trifling that I can only quote Saussure, though his remarks afford nothing for the present purpose. In my own observations, it becomes a substitute for hornblende schist, alternating with gneiss, while both frequently occur together. In general, it is in small quantity; and thus it is found dispersedly in many parts of Scotland, and in the Shetland islands. In one instance it forms a distinct and considerable prolonged bed, well known in Glen Elg, where it occupies the summit of a hill, re-appearing in Eilan Oransa on the shore of Sky. It is likely that it forms similarly extensive beds in the Swiss Alps. In one instance only, I have found it forming laminæ in primary limestone, in Atholl; and it occasionally occurs in micaceous schist, where this is intermixed with chlorite and hornblende schists. It accompanies serpentine, in Shetland, under an association leading to no conclusions; and I have recently described its peculiar connexion with Chlorite schist. That it furnishes specimens to collectors, is all that I can further say repecting its natural history.

CHAP. XXIX.

Quartz Rock. Red primary Sandstone.

As Quartz rock has been either entirely overlooked or misapprehended by all systematical writers, and, until I had described it, by all observers, it is probably rare in Europe. It would be unbecoming to suppose such oversights and errors, had it occurred, as it does in our own island, in countries so often examined by geologists of reputation: though others must explain the cause of its fate here, as, in so doing, they may learn to estimate more correctly, the teachers and writers in whom they have trusted. Its history is therefore drawn solely from my own observations in Scotland; the materials having been originally published in the *Geological Transactions:* while I may now name the few instances in which it has been noticed elsewhere, since it thus received a leading place in the system of rocks. Von Buch describes it in Norway, and Brongniart in La Mancha; the fictitious Ali Bey mentions it as abundant near Mecca; and it occurs near Lima and in Brazil, in tracts equalling that of Jura: though if Humboldt was unable to determine its stratification or explain its nature, we must remember that it had not then been noticed in any geological writings. Future observers, now informed of its nature as well as its existence, will probably find this important rock much more frequent than it was suspected to be while yet undescribed. We are taught, even to see.

Quartz rock, like limestone and argillaceous schist, has its counterpart in the secondary sandstones, but is not exclusively formed of the mineral whence it derives its name. The more important varieties may, how-

ever, all be reduced under three divisions, consisting of quartz alone, of quartz and mica, and of quartz and felspar. A compound of quartz and schistose clay is far less common; but all this is detailed in the Classification of Rocks. Its texture is interesting, as presenting examples of the purely mechanical, and of the chemical, together with instances of that mixed or intermediate nature so common in the primary rocks. In the purest examples of the chemical or crystalline texture, it consists of quartz alone, sometimes undistinguishable from that of veins, except by a laminar structure, or a tendency to divide into thin beds, parallel to the plane of stratification. In the second variety, grains of felspar, rounded, not crystallized, are sometimes also imbedded in continuous crystalline quartz. The crystalline texture gradually gives way to an obscurely granular one; in which the quartz is either confusedly crystallized, or is an aggregate of grains united by a cement of the same substance. This granular texture varies much, in the size of the parts and the compactness of the whole; till, becoming lax and arenaceous, the rock cannot be distinguished from many secondary sandstones. In these cases, the texture is chiefly mechanical; the grains being rounded, and the points of mutual contact few; while this happens also in that variety which contains felspar. But it becomes unquestionable when the rock consists of agglutinated gravel: while rounded pebbles dispersed throughout the beds, with angular and rounded fragments of dissimilar rocks, such as clay-slate, jasper, and micaceous schist, leave no doubt of its origin.

It is worthy of remark, that Quartz rock sometimes contains cylindrical, generally flattened concretions, similar to those of the secondary sandstones; adding a singular point of analogy to those already mentioned.

Had these been found in a secondary sandstone, they would have been considered as originating in the stems of vegetables: but until we find more decided organic fragments among the primary rocks, no geologist will receive them as such; particularly when it is predetermined that this must not be. Yet if the coal in those rocks has originated in vegetables, these concretions may also have been derived from the same source. When it contains cavities lined with crystals of quartz, these must be attributed, as in the trap rocks, to watery infiltrations of silica. Contortions, so common in the primary strata, scarcely ever occur in quartz, rock; a few trifling examples only, having fallen under my notice: but flexures on the large scale are very conspicuous in the island of Scarba. The probable reasons were formerly stated.

Of all the primary strata, quartz rock presents the greatest regularity of stratification. The evenness, persistence, repetition, and distinctness of the strata, are such, that it is matter of surprise how its true nature could have been mistaken, or how it could ever have been confounded with granite, as it was by the well-known describers of Jura; even had its mineral characters not been so explicit. It is a lesson to those who set about to construct systems of geology from books; but a lesson thrown away: still more thrown away on those who describe what they have not knowledge to see. In this and the associated islands, the Geological student may examine a series of stratification on a gigantic scale, as perfect as if it was displayed in a model; and, for the particulars, I may refer to the account of the Western Islands.

The thickness of the strata varies, but is more often nconsiderable than otherwise; those of a few inches or feet in depth being common; as those of many

yards are rare. They are frequently divided, like the argillaceous schists, by joints; thus breaking into rectangular and rhomboidal fragments. Hence, where exposed to the force of the sea, they are often undermined, so as to form caverns; of which Jura and Isla present magnificent examples; yet eclipsed by the superior splendour and number of those at Loch Eribol in Sutherland. The total thickness of the deposits may easily be estimated in various parts of Scotland; as in Ben Gloe, in Sutherland, and in the islands already mentioned. As it occupies the whole depth of Jura, from the sea to the summit of Ben-an-oir, the thickness of this collection of strata cannot be less than 2200 feet, while it may be much more: nor is it much less in Canasp, on the west coat of Sutherland. If it is thus a very important member of the primary strata, in depth, it is not less so in extent; occupying very considerable spaces in Shetland, Sutherland, Ross, Banff, Perthshire, and in many other districts of Scotland besides these Argyllshire islands.

Quartz rock alternates with every one of the primary strata, and, like all of these, has therefore no fixed place in the series. I know not that it has even a predominant one; but it is most abundant in the gneiss districts, though the most continuously extensive mass, that of Isla, Jura, and Scarba, is chiefly associated with argillaceous schist. Its alternations with gneiss are sometimes on a large scale; at others, the beds are so thin and so rare in proportion to those of the accompanying rock, that they would be called subordinate by those who delight in that term. In this case, the variety is generally that which contains felspar; often passing into the gneiss by acquiring the other necessary ingredients of that rock. Its alternations with micaceous schist are the next in frequency;

as transitions are also more common, and the distinction less easily made. In this case the modification of the quartz rock is that which contains mica; so that as this increases in quantity, the common limit of the two is evanescent. The geologist must here be guided by the predominant characters of the whole mass, not by that of a specimen; nor must he be surprised if he cannot always find fixed distinctions between rocks so radically the same in composition. These alternations are sometimes therefore so gradual as to present a complete series of transitions; while, in other cases, as in Jura and Scarba, they are perfectly defined, even on a very minute scale. In such cases of minute alternation, it is as common for the micaceous schist to be subordinate in quantity to the quartz rock, as the reverse.

Alternations of quartz rock with argillaceous schist have occurred to me only in Glen Tilt, and in the chain of islands already mentioned; yet always on a small scale, and in beds of inconsiderable thickness, sometimes extremely thin, and beautifully regular. In the islands of the chain of Jura, there is a triple or quadruple series, consisting of quartz rock, with micaceous and with fine and coarse argillaceous schists, in endless alternations; so that every one of those rocks is proved to be alternately more antient and more recent than the others; still further showing, could that be necessary, the fallacy of those hypotheses which lay down a fixed order of succession among the primary strata. Where it alternates with the coarse argillaceous schist, or graywacke, its beds pass into that rock through the conglomerate structure already described. Its analogy to the secondary sandstones, here, becomes apparent; the same mixed composition pervading both, as in the occasional con-

nexion between the recent coarse shales and the sandstones to which they belong. The whole of the association, indeed, between quartz rock and argillaceous schist, bears a striking resemblance to that between shale and sandstone in the secondary class. Of the connexion between quartz rock and the primary red sandstone I must speak immediately.

The external character which quartz rock gives to a country, and particularly to the mountains composed of it, is generally remarkable, and leads to its detection, even at a distance. Such hills are commonly of a conoidal shape; and, under any form, are bounded by a smooth flowing outline, rarely disturbed by the asperities so generally characteristic of micaceous schist. They are commonly also covered, on the steeper parts, with fragments, on which no soil accumulates; their naked whiteness being seldom concealed, even by the growth of a lichen. From this whiteness, often so dazzling in the sunshine as to emulate the effect of snow, the composition of these mountains can often be conjectured at a distance. Although these ruins bespeak the degradation of the strata, the disintegration of the rock itself is everywhere scanty; the soil being consequently thin, and consisting of little else than sand mixed with a portion of the black earth of vegetables. Hence they form the most sterile of all the soils of Scotland; while the same character appears to belong to this rock wherever it has been observed.

The theory of quartz rock is sufficiently obvious. Its regularity of stratification bespeaks its aqueous deposition, as does its mechanical structure in the cases already described. Where this structure is combined with a chemical or crystalline texture, we have only the same difficulties to contend with as in the

secondary sandstones: which are even found highly crystalline and compact, as in Fife, already noticed, where a bed in the coal strata is a compact quartz without any marks of mechanical origin. The fundamental difficulty, in all these cases, is that which affects the whole history of silica. It has been once extensively dissolved in water, as is proved by a thousand facts; and is still soluble, if in a less degree, as we know from events of recent or daily occurrence. Such causes may have consolidated many primary deposits of sand into compact quartz rock, whether felspar and mica were ingredients or not. But, as in gneiss and micaceous schist, heat cannot have been inactive, especially where it alternates with these: while it may as well have produced this effect from some general cause, as it has from local causes when trap is present. The quartz bed of Fife is, evidently, a secondary sandstone consolidated by heat: from its position, from the analogy of the cherts thus produced, and, still more, from the fact that, in Sky, the recent sandstones are converted into solid quartz in several places, precisely where they come into contact with veins or masses of trap. In this case, the action of heat is admitted, and the effect in question has taken place; and, similarly, in Ben-na-chie and in Glen Tilt, where beds of quartz rock are intermixed with granite, they are indurated to compact quartz when pure, and converted into jasper or chert when they have contained felspar or clay; these changes being all co-extensive with the vicinity of the granite. Here, there are similar effects from a cause which, if not universally admitted to be the action of heat, will not probably for ever be denied.

The indestructible nature of most of the varieties of this rock, points it out as adapted for architectural purposes, though hitherto neglected. It can also fre-

quently be procured in parallel beds of various thickness; while, often possessing natural joints, like many other schistose rocks, it breaks readily into fragments, easily trimmed by the hammer. The difficulty of producing a smooth surface by the pick, might limit its uses to certain classes of masonry; but in those, the facility of giving it a form fit for building, would render it an œconomical substitute for granite, which it also far excels in durability. As a lining for furnaces, its value is obvious.

The want of foreign observations on this rock, prevents us from knowing whether it is a repository of metals. If it be excluded from the metalliferous rocks because it contains no metals in Scotland, we might draw the same conclusion with regard to many others. Yet at Tyndrum, as noticed under micaceous schist, galena and blende are found in a hill which consists of alternate beds of quartz rock and micaceous schist, and in which the former is nearly as abundant as the latter.

Red primary Sandstone.

I have associated this in the same chapter with quartz rock, for reasons which will ultimately appear; but before proceeding to its history, I must limit its range as formerly given in the account of the Western Isles. A re-examination of some of these districts has shown, more clearly, what I then suspected; that some of the examples then quoted belong to the *old* red sandstone; the difficulty of distinguishing them where the secondary follows the primary one, especially in conformable order, being extreme, or almost insurmountable.

The varieties of this sandstone are very limited; nor does it require any further general definition than that of the secondary red sandstone. It is, fundamentally, an aggregate *of quartz* and red felspar, varying

in the fineness of the ingredients, exceedingly indurated, and the grains bearing the marks of previous mechanical attrition. In this respect, indeed, it often equals common quartz; the whole appearing as if cemented by a general solution of silica.

Sky presents the most easily ascertained examples of this rock: though it occurs also in Ross and Sutherland, associated with quartz rock. The beds, which follow the general direction, present almost every possible dip, being directed also to different sides of the vertical. If their present lateral breadth be considered the same as their original depth when they were deposited, they will be esteemed to occupy a thickness of many miles. But, I have pointed out how such an estimate may be fallacious; though, under any view, they will form a mass of enormous thickness. In Sky, this series of beds is also in parallel contact with the gneiss with which it alternates; but, as in most cases of erected strata, it is impossible to decide which was originally the lowest. Independently of this alternation, by which its primary nature is established, it also graduates into the gneiss, producing intermediate substances noticed under the head of that rock, and consisting in different modifications of chlorite and argillaceous schists, from fine slate to a perfect conglomerate, occasionally also containing garnets. These alternations are sometimes very frequent, and the beds of schist are minute in proportion to the sandstone; in other cases, considerable accumulations of the schistose beds, unmixed with sandstone, occur. Conglomerates of various structures alternate with the finer sandstone, as in the case of the secondary strata. Lastly, quartz rock is found in the same places, alternating with this sandstone, and forming an integrant member of the series; with the same variety of character as where it occurs with micaceous schist.

The reasons for ranking this sandstone in the primary class are now apparent, notwithstanding its resemblance to those of the secondary division; and, that it is not even the latest of the primary strata, is evident from the preceding history of its connexions. No objections need arise with respect to the application of the term primary, to a rock composed of re-united fragments, since the same character occurs in quartz rock, and also in micaceous schist; as there are also striking analogies between the former series and the present, in many important particulars. The obvious differences, indeed, frequently consist in little else than colour; felspar being equally present in some kinds of quartz rock, though of a paler hue than in this sandstone; while both have been generated from gneiss and granite, in these cases, as, in others, from those, and from other strata of a former series, as noticed in the chapter on the Revolutions of the Earth.

I may conclude these remarks by observing, that they who do not choose to admit a new distinction, may consider this as a modification of quartz rock. But the magnitude and distinctness of the masses, with their marked appearance and separation from the other forms of this substance, seem to give it a claim to a place somewhat more important than would arise from mere distinction of colour; though I willingly leave it to the judgment of others. If it is considered as unwarrantably introduced into the antient catalogue, I cannot quote any confirmation of its existence elsewhere, from the writings of foreign authors. But as M. Cordier has recently professed to me his belief in a red sandstone, followed by a schist, and anterior to that "old red sandstone" which he takes care to distinguish from the red marl, it is likely that the rock which I have now described does actually exist on the continent of Europe.

CHAP. XXX.

Argillaceous Schist.

As the present title includes all the primary varieties of this rock, it comprises the Clay-slate and the Graywacke of Geologists; excluding all the similar substances in the secondary class, under the term Shale. The distinction is a geological, not a mineral one; and the present arrangement, or innovation, has long been needed: since the confusion originally produced by the Germans, and continued by their followers, in adopting and misapplying the term Graywacke, has rendered their writings worse than useless. This division of the primary schists appears to have been first founded on erroneous observation, as it has been continued by those who find it easier to follow authority than to observe.

It was never, indeed, very easy to learn the opinions of Werner; yet he appears to have mistaken the red marl for the lowest sandstone, thus erroneously assigning to it the first place among the secondary strata. Hence, confusion was first introduced into his views of these, while the mountain limestone and the old red sandstone became excluded, and placed either in his *transition*, or in the primary, series.

Now as this sandstone series often contains as much, or more of argillaceous schists, than it does of sandstones, and as many of these are formed of fragments, being, in a mineralogical sense, coarse graywacke, it appears to have laid the foundation both of his graywacké and his *transition;* while it is easy to see how exactly it tallies with all the characters which he has given, as it occurs with us. The remainder of the confusion follows of course. They who were guided by words

rather than things, and to whom authority stood in place of reasoning and observation both, easily transferred the term graywacke to all the argillaceous schists of similar structure; and the word *transition* becoming a ready excuse for neglect, or a substitute for knowledge, these strata became graywackes and transition rocks whenever it was convenient, either for the system, or for the observer's ease or ignorance. I should think this criticism misplaced, had it not been necessary for the elucidation of a most vexatious obscurity in geological writings. In reflecting on this abuse of terms, we are almost inclined to wish that the business of Geology could be carried on without them. There would at least be fewer writers, when descriptions must be substituted for phrases; nor would so much time be occupied in undoing the knots which ignorance has tied, and which have made a warfare of a peaceable pursuit.

The examination of Nature confirms the propriety of the arrangement which I have thus adopted. There is no extensive mass of fine schist, or *clay-slate*, in which the coarse, or *graywacke*, does not occur, while the reverse is also true: and, in all cases, the geological relations are the same, or the identity perfect. Moreover, the two structures pass into each other by insensible gradations; sometimes vertically, in a bed or series of beds, and at others laterally, in the same bed: while what is true of the larger tracts of argillaceous schist is equally so of the smaller masses found among the primary strata. And the *priori* reasoning supports as it explains the facts; as they are explained also by the analogy of the sandstones of varying texture: both of them being aqueous deposits of fine and coarse materials, thus separated by the action of water. The geological uniting of these, lastly, equally justifies the present arrangement.

The general definition of argillaceous schist is, an indurated schistose clay, either simple, or mixed with quartz, occasionally, with mica also, and with other ingredients. In Clay-slate, no quartz is visible; in Graywacke, the basis of clay-slate may contain mica only, or quartz sand, or both; and also gravel of different kinds, becoming at length a conglomerate of various fragments or pebbles, united by indurated clay. The details of these, and of the varieties termed hone, whetslate, &c., will be found in the Classification of Rocks.

The internal structure of argillaceous schist is various, though not always depending on the fineness of the ingredients. The schistose, or laminar one, is more or less perfect, in both varieties. In clay-slate, it has no apparent cause; but, in graywacke, it often depends on the occurrence of a micaceous lamina, or of minute scales of that substance. In such cases, the laminar character depends on the gradual deposition of the materials; while the analogies of micaceous schist, gneiss, and the fissile sandstones, would lead us to infer that it was always parallel to the plane of the bed. That, indeed, is often the case, particularly where thin beds of this rock alternate with micaceous schist, quartz rock, or gneiss. In other instances, however, it is not conformable to the stratification, being placed at different angles towards it, and, sometimes, even transversely. When the beds themselves are exposed, this fact is easily determined; while, if the direction of the fissility is alone seen, an erroneous judgment is often formed respecting the real positions of the strata. If there are sometimes no means of correcting this judgment, the real stratification can, at others, be ascertained by examining the internal structure; as I long since showed to those who have committed this frequent error: the mode of separation

of the finer and coarser materials, during their deposition, evincing that any alternation between these must be parallel to this plane; as the facts themselves also prove. If therefore any doubtful bed presents such an alternation, whatever direction its laminar tendency may possess, the plane of stratification must be conceived parallel to that; and by this criterion that question can be determined; while the proof that the fissility depends on concretionary structure, and not on deposition, in such cases, is evinced by the fact that it not merely crosses the stratification, but is often continued through both the varieties.

The laminæ are sometimes straight and even; at others, more or less minutely undulated, as in micaceous schist; these modifications being most remarkable in the finer clay-slates, though occurring also in the graywackés. Occasionally, they present irregular convexities and concavities; while this is most common in the graywackés. In a few instances, they possess a fibrous texture, sometimes further combined with the laminar. The coarsest graywackes are sometimes laminar; at others losing that texture, and becoming massive conglomerates. They occasionally contain grains of felspar, deriving thence a porphyritic appearance: and large fragments of quartz sometimes occur in the finer schist, without destroying its fissility.

All the varieties divide naturally at right or oblique angles to the laminæ; the divisions being commonly filled with ochrey matters, and the joints smooth. The rhomboidal and other forms are familiar; sometimes producing long beams adapted to architecture.

Laminæ of chlorite and talc occurring, confer on those parts a silky or plumbaginous lustre; as veins of quartz and of calcareous spar are common; both substances often existing in the same vein. Veins of

chlorite are also frequent, but other venous substances are of an accidental nature. Lastly, the argillaceous schists contain nodules or cylinders of the same material, possessing no internal structure, round which the laminæ of the including rock are bent: while these, with other concretionary forms, have led bad reasoners to false conclusions respecting the origin of these schists.

The transitions of fine clay-slate are into drawing-slate, fine chlorite schist, micaceous schist, siliceous schist, and hornblende schist; the three latter occurring only in the vicinity of granite, trap, or gneiss. Those of graywacke are into coarse chlorite and micaceous schists, quartz rock, and sundry conglomerates. It passes, further, into red sandstone, where these approximate; and as it is also a member of that series, though under the name of shale, this has particularly led to the erroneous inference noticed under the Red sandstone, that there was a geological gradation between the primary and the secondary classes. Further, it passes into schistose clays, not to be distinguished from those which occur among the secondary strata. The gradations into gneiss, and into the red primary sandstone, have been already noticed. Organic fossils of various kinds are sometimes contained in argillaceous schist, and even in considerable abundance, as formerly observed: Wales presenting remarkable examples of this occurrence. It also occasionally contains certain crystallized minerals, such as chiastolithe, garnet, staurotide, and others.

Argillaceous, like micaceous schist, occurs in two modes, either forming huge masses and occupying large tracts, or alternating in smaller proportion with many other rocks, and often in a very intricate manner. In the first case, like the other primary strata, it is dis-

posed in beds of various dimensions; under the usual variations of dip and direction. These are also subject to flexures, yet seldom displaying such intricate contortions as micaceous schist or gneiss, except when in contact with granite or trap, or traversed by veins of these substances. Moreover, the laminæ are sometimes bent or contorted, even when the beds are regular and their planes parallel. To a cylindrical or conical flexure, occurring in these beds and in the other primary schists, the term mantle-shaped has been applied by those who find strange virtues in words. This, and other such terms, I have designedly avoided; reserving also the only remark which they require, to this place. All the primary strata generally preserve an uniformity of direction and inclination, unless granite be present, in which case they put on these forms, and commonly in proportion to their proximity to this rock. The causes must have long since been obvious.

In alternation with other rocks, it sometimes occupies very small spaces; a single bed occurring among a large mass of strata, not to appear again throughout a large portion of the series, being also variable in breadth and persistence, and sometimes a mere lamina, extenuated to nothing after a very short course. Occasionally, many are accumulated in depth, without lateral persistence; thus forming insulated and irregular masses, not unlike the independent deposits among the secondary strata. In other instances, it occurs in considerable tracts, containing occasional beds of other substances: or in a long succession of alternations with one or more others; forming, lastly, an occasional member in a very irregular and various series; as will presently be noticed.

With respect to the positions of this rock towards the primary, it immediately follows granite in Cornwall,

in Scotland, in Jersey, and elsewhere; both varieties being indifferently lowest, as in other cases where the same rocks occur in more limited portions. In all these examples, it is followed by the secondary strata; nor do I know that, on the great scale, any other primary rock has been observed succeeding to it, although, on the small, I have found every one of them. The alternations which it then presents are numerous and intricate; and the history of these will determine the nature of the rocks which it follows and precedes, as that will show that it has no fixed place in the system, considered as a mere rock. That its larger masses may follow any primary stratum, and thus also be still the uppermost, it is superfluous to say.

A remarkable example of its alternations, is the compound series which terminates the Highlands to the southward, and is followed by the lowest red sandstone; misrepresented as a mere mass of clay-slate. The rocks in question consist of different micaceons and chlorite schists, with graywackes equally various, clay-slate, and limestone, and more rarely, with gneiss and hornblende schist, irregularly intermingled, and often presenting transitions between several of the members; as from the micaceous to the chlorite schist, and from the latter, into graywackes or clay-slate. Yet more or fewer of those are found in different parts of this long and narrow deposit, which is sometimes reduced to the argillaceous schists alone: the whole graduating into the micaceous schist which it succeeds, so that the limit is scarcely ever definable.

Its next remarkable association occurs in the chain of Isla and Jura. Here, both the varieties alternate in frequent repetitions with quartz rock and micaceous schist; the graywackes often passing into the conglomerates of the former; while in some parts, the united

clay-slate and graywacke occupy considerable spaces, without the intervention of the other rocks; limestone also forming an occasional part of this series. I may refer to the accounts of Chlorite schist and Primary sandstone, for some other associations of this rock; as, under gneiss and hornblende schist, I have described its peculiar connexions with those substances. I need only add, that beds of argillaceous schist sometimes occur in company with quartz rock and micaceous schist; in a very independent state, and far removed from any masses of a similar rock; as may be seen at Balahulish.

I should not be at the trouble of adding any thing on the theory of argillaceous schist, since it is but that of most of the preceding strata, had it not been misapprehended and disputed. That both the fine and the coarse were originally deposited from water, must be apparent, as must the nature of the original materials. But there are cases in which it must subsequently have been exposed to heat, if it has not in every one; since, in this way, and no other, can be explained the formation of the minerals of igneous origin within it, and indeed of any minerals belonging to its texture. The case is that of micaceous schist and gneiss; and thus too are the porphyritic graywackes explained. In the same manner, probably, must be explained its several concretionary structures. It is also connected with the theory of this rock and of micaceous schist both, to remark, that at its contact with granite, it is often converted into the other for a small space, as it is also, if more rarely, into gneiss; while if any one still continues to maintain that these are distinctly stratified substances, and not cases of igneous influence, the theory is proved by the fact that the same changes occur where granite veins penetrate, in a manner which

precludes all possibility of a separate stratification. In reality, this and the similar facts noticed all through this work, imply the whole theory of the primary strata, as rock species, distinguished from the secondary ones.

As argillaceous schist forms extensive tracts, it is easy to study the characters which it confers on a district. In these, there will be found considerable variety, as in North Wales, Cumberland, Cornwall, and the South of Scotland. Of these, Snowdon attains a considerable elevation, as does the mountainous tract of Cumberland; often presenting faces of naked rock, with a variety of ruggedness equalling that of micaceous schist, as in Snowdon, and Langdale pikes, while in Skiddaw and elsewhere, the smooth conoidal and low rounded form more generally characteristic of this rock prevail; as well as in Wales, widely, in the Isle of Mann, in Cornwall, and in the South of Scotland; though, in Cardiganshire, it is disposed in sudden hills of small elevation, marked by frequent protuberances. And as it generally decomposes readily into a clay, of different degrees of tenacity, it presents a great variety of soils, favourable both to agriculture and to the growth of wood. Its œcononical uses are well known.

Metalliferous veins occur in both the leading varieties of this roek. The tin and copper veins of Cornwall are common to the schist and the granite, and it necessarily therefore contains the other metals mentioned under that head. In Scotland, it forms the great mine of the Lead-hills; and, in other countries, it includes silver, copper, zinc, and more rarely, cobalt, and gold.

CHAP. XXXI.

Diallage Rock.

This remarkable compound is among the more rare of the primary rocks, and is, therefore, not very well known. Fortunately, our own country contains one conspicuous tract of it, where its chief characters may be examined, and whence the present description must be derived; since foreign writers have not given us very satisfactory accounts of those which exist on the continent. This occupies the whole of Balta, and portions of Unst, Wya, and Fetlar, in Shetland. It occurs also, in Piedmont, in Corsica, and at Crems in Austria; being further said to form the Zoltenberg in Silesia, and to be found in Norway, even as far as the North Cape. It is to be wished that the details of its geological connexions, in all these situations, were carefully studied and described.

This rock is a compound of diallage and felspar. Its varieties depend on the nature of the felspar, which is either the common or the compact kind, on the varying proportions of the two ingredients, and on the various magnitude of the integrant parts. For these and other details I must refer to the Classification of Rocks; the mixtures of serpentine and diallage being ranked under the varieties of the former substance. Independently of its stratification, Diallage rock presents some peculiarities, whence arises that disposition to irregular fracture which so generally obscures the divisions of the strata. It is often penetrated by thin laminæ of talc, chlorite, or mica; in consequence of which it yields in numerous directions. It is also often intermingled with short irregular veins or masses of the felspar which forms its chief ingredients; and thus

also it varies much, even within very narrow limits. The texture is often confusedly crystalline, like that of granite; the rock breaking indifferently in any direction, though commonly with great difficulty, on account of its extreme toughness. This is more particularly the case in the small-grained varieties, and in those where compact felspar is an ingredient: the larger-grained kinds, and those containing common felspar, being comparatively frangible. But it is often fissile in one direction, while it yields with difficulty in the opposite one; the texture resembling that of gneiss, or being imperfectly schistose, and the fissility arising, similarly, from a parallel tendency in the crystals of the diallage. It often also contains those veins called contemporaneous, in which the two minerals are intermixed in large portions or irregular crystals, or in which one of the constituent minerals exists to the exclusion of the other.

The stratification of the Diallage rock of Unst and Balta is so obscure, that it might, on a superficial view, be considered as an unstratified rock, analogous to granite. But more careful observation discovers that it is disposed in protuberant masses, in lines parallel to the general direction of the neighbouring strata, and that all the points projecting into the sea, preserve the same bearing. This disposition is further evinced in its regular juxtaposition to the strata of gneiss, and of micaceous and argillaceous schists, which it follows, and by its occasional alternation with these rocks, however its scanty exposure in the interior, and the lowness of the shores, may deprive the observer of the unquestionable evidence derived from the forms and divisions of the beds; which are also obscured by the innumerable fissures among which they are confounded. But in Houna, the stratification is perfectly distinct; the

direction and the dip of the beds being easily traced, and their dimensions also admitting of measurement. At Fedaland point too, where thin beds of this rock are interposed among other primary schists, the regularly stratified disposition is obvious.

Like many more of the primary strata, Diallage rock presents a considerable variety of connexion; being found in contact with gneiss, with micaceous, chlorite, and argillaceous schists, and with serpentine. It also alternates with every one of these rocks; while the large masses contain thin beds of these substances, and of hornblende, talcose, and actinolite schists, with, more rarely, serpentine. It further appears to pass into talcose and chlorite schists; and in those cases, the essential mineral, diallage, appears to change its character so as to graduate into talc, or chlorite: felspar remaining. The apparent passage into serpentine occurs where the diallage rock approximates to that substance. In this case, the felspar seems to be excluded, and a serpentine substituted in its place; though from the dark colour of the compact felspar in this compound, and the hard nature of the serpentine, they are scarcely distinguishable in the state of minute admixture with diallage.

In concluding this account of its geological connexions, I must observe, that all reports seem to note its frequent or peculiar connexion with serpentine, though it is not easy to conjecture what necessary affinity should exist between them. This appears to be the fact on the continent of Europe, as it is in Cornwall and in Shetland; in these islands, even the smallest masses of it are accompanied by portions, equally insignificant, of Serpentine.

In this imperfect state must the history of Diallage rock remain, till foreign geologists shall furnish us with

more accurate accounts than they have usually done of rocks in general. Its theory must therefore remain obscure. From my own investigations, it should bear an analogy to gneiss; having been originally deposited, as a stratum, from water, and subsequently mineralized by heat. But if the facts respecting it, quoted in the subsequent history of Serpentine, are authentic, it is, like that, an occasionally venous rock, and might therefore claim a similar place among the unstratified substances. Thus, analogous to gneiss in one place, it should be analogous to granite in another; while this double character is perfectly consistent. Thus, further, while nearly resembling hypersthene rock, it might be, like many traps or porphyries, a member of both classes; and it is, in reality, a secondary as well as a primary rock, if the facts to which I have alluded are true.

Though, in Shetland, it confers no particular character on the form of the land, it is easily recognised, even at a distance, by the peculiar aspect of the surface. Being, like serpentine, unfavourable to peat, and mouldering with difficulty into soil, it protrudes every where, with an effect resembling that which is produced by scattered blocks of granite, while the intervals are distinguished by the greenness of the pasture. Balta displays the character of this rock when exhibiting a bare surface: its precipices being peculiarly rugged, without marks of stratification, and broken into innumerable angular parts, by fissures in every possible direction, but bearing no resemblance to granite, or trap, or any other rock.

CHAP. XXXII.

Serpentine.

This rock has never been duly studied by those who have had opportunities of examining it widely, and thence it has continued to be one of the difficulties of Geologists. If my own views of its nature are derived from Britain, they are founded, as on all other occasions, on those essential facts and analogies which seem to constitute the laws, or the philosophy of Geology; and thence, even this limited field of observation should give the truth, as I trust it has done, in every other case, where the same proceeding has been followed, under a careful induction of essential facts, derived from the same narrow but rich field. And hence, in this case, as in all others, when I have borrowed from authors, it has been under rigid care, arising from the conviction that Nature cannot contain opposing truths.

Serpentine occurs as a stratified, an unstratified, and a venous rock; and thence it might have stood in either of the two first great divisions. If I have here vacillated, in changing its place to the former, having included it among the unstratified in the Classification of Rocks, Geologists may determine as it pleases them, respecting a rock which occupies this double place, though, in both, of igneous characters, and thus bearing an affinity both to granite and gneiss. Thus also have I placed it in the primary class, though occurring, like siliceous schists and others, in both.

It is difficult to ascertain, from foreign authors, under what precise distribution most of the well-known masses of serpentine on the Continent of Europe exist; as geological language has not always been very definite respecting stratification, and as, on that ques-

tion, there is too often an hypothesis which vitiates the observations. But, in our own country, it presents very few instances of a form, even approaching to this. Most of the smaller, and even some of the larger, examples, are shapeless masses, or irregular nodules, if that term may be applied to bodies of large dimensions. In this respect, however, Serpentine is somewhat analogous to limestone; since among the primary ones, irregular masses are not uncommon. Limestone is, in fact, occasionally entitled to be considered unstratified, as much as Serpentine; but it must be remembered that it does not form veins, except as calcareous spar, and that it has no proper transition into other rocks.

The masses of Serpentine vary in dimensions, from a mean diameter of even a few inches to one of miles; though in the latter, a more perfect examination than the ground will often afford, might discover traces of stratification not visible on a general view. This is the case in Unst; where, throughout a very extensive tract, no marks of the stratified disposition can be traced, while in other places, it is perfectly distinguishable. At Portsoy and in Sutherland, it occurs in a form partaking both of the nature of a stratum and of an irregular mass; as happens in the primary limestones. Such bodies are included among other strata; and, for a certain space, at least, they have two flat and somewhat parallel sides, determined by those of the including rocks, but which soon converge in every direction, so that the mass becomes extenuated all round till it vanishes. If, in Unst, the stratified disposition is often imperceptible, it may arise from the imperfect view obtained, in consequence of the nature of the surface, and from the irregular manner in which it is fissured: whence the divisions of the

strata are confounded among the multitude of discordant rifts, as happens also in diallage rock. Where visible, it admits of no doubt; the indications of the strata being prolonged in a parallel direction to those of the accompanying schistose rocks, and dipping in a conformable manner. The same appearances, if less explicit, may be traced in the neighbouring island of Fetlar. I cannot quote any further examples of this disposition; the apparently similar indications in Aberdeenshire being extremely questionable.

The associations of Serpentine with the primary rocks are even more various than those of limestone; since I know not that this has yet been found involved in granite, as the former is. In Aberdeenshire, irregular masses of Serpentine are enclosed within that rock, excepting, of course, where it is itself visible. I know not that this appearance is an objection to the originally stratified nature of Serpentine; since fragments or masses of other rocks are often found in this position. But it is worthy of remark, that, at the contact of the granite and the serpentine, there is generally a lamina of steatite or of talcose schist; while there is occasionally an uncertainty of characters at the junction, which may even be termed a transition between the two. We shall presently see the value of this observation.

In Sutherland, and in Glas island near Harris, serpentine is found imbedded in gneiss; having two parallel sides, or assuming the appearance of a short stratum, while in this association, the external parts are commouly intermixed with hornblende and with actinolite; so that an irregular transition into the surrounding rock is produced. In Shetland it is associated, indifferently, with gneiss, and with micaceous, chlorite, and argillaceous schists, as it is with the latter rock

at the Lizard in Cornwall, in Anglesea, and at Portsoy. At this latter spot, the intermixture of the different rocks is somewhat intricate; gneiss, chlorite schist, limestone, and serpentine, all occurring in an irregularly alternating order. In Aberdeenshire, similarly, it occurs in company with almost all the primary class except quartz rock; with which I have never yet seen it associated. If, lastly, it bears a peculiarly intimate relation to talcose schist and diallage rock, that has been noted in the descriptions of these.

Thus far, the history of Serpentine has also justified its rank in the primary class; nor need it be deprived of its place there because of the circumstances about to be described. In Sky, where trap veins penetrate white crystalline limestone, the parts in contact with the calcareous rock consist of serpentine, to the depth of an inch or more. There is also a gradation between the serpentine and the trap, which is a black claystone; so that a perfect transition takes place between the two. Similar appearances, less remarkable, occur in the same island, where trap veins intersect a series of calcareous sandstones, being further displayed, but on a more extensive scale, and in a more distinct manner, at Clunie in Perthshire, as I originally showed. Here, where a basaltic vein traverses limestone, the sides of the former consist of serpentine to the depth of four or five inches, passing into the basalt by an imperceptible and perfect gradation, while the rifts are also filled with varieties of steatite and asbestos. In these instances, moreover, the limestone near the contact is intermixed for a similar space with steatite; so that there is often an almost uninterrupted gradation, through steatite and serpentine, between the two highly discordant substances, basalt and limestone. This connexion between basalt and

serpentine is not less remarkable than the other peculiarities of the latter rock; and is further indicated by the frequent occurrences of steatite in the traps, and of hornblende in the Serpentines.

Some observations long posterior to my own, have not only confirmed them, but proved what I then suggested, that veins of Serpentine alone might exist, since that substance formed portions of trap veins. Mazzari has found such veins in the alpine limestone of the country of the Avisio; while Parolini and Webb have observed basalts and amygdaloids containing steatite, then becoming serpentine, and lastly sending veins of this substance into the mountain called the Giants' bed, on the Bosphorus. The transition of trap into Serpentine occurs also at Predazzo in the Tyrol, in the same manner as at Clunie; and it is remarkable that where the veins occur at Santa Pe in the Pyrenees, they consist indifferently of hornblende rock, basalt, and serpentine. In South America, at Venezuela, serpentine and greenstone are said to alternate. According to Cordier, the basalts of the Bosphorus are of volcanic origin; but whether this be the fact or not, the existence of volcanic serpentine in the form of veins seems established; as an amygdaloidal rock in the volcanic mountain Akkrefell in Iceland, is traversed by such veins, of four feet in thickness. I must add to these important facts, that the transition between granite and serpentine, which I originally observed in Aberdeenshire, is now spoken of by Mazzari as unquestionable.

Here, then, Serpentine displays all the characters of an unstratified and venous rock, of igneous origin. The evidence seems as complete as it can well be; and if it does not receive some additional support from another analogy, that may at least remove an objection

derived from its peculiar texture, so often earthy, and so seldom crystalline. The same character is frequent in the rocks of the trap family; and whether it is a consequence of partial decomposition, as there suggested, or an original form, it is obvious that the same difficulty applies to both.

An observation of Brongniart, imperfectly made, and therefore at first disputed, becomes explained under more accurate observation consequent on the views which I originally suggested, while it tends to confirm the theory which I have given of Serpentine. The error and its correction will serve to teach the young observer the necessity of preliminary and correct knowledge. In various parts of the Apennines, as at Prato, Pietramala, Volterra, &c., it was found lying above Diallage rock, followed downwards by jasper and by the secondary limestone; while he concluded that the serpentine of La Bocchetta, Mussinet, Baldissero, and Castellamonte, was similarly situated. Hence, not only Serpentine, but diallage rock, and jasper also, ought to be secondary rocks of a very late date. Admitting the facts, in their fullest extent, I had thus explained them. I have elsewhere shown that jasper is sometimes a member of the trap family, and that it is often peculiarly associated with these rocks, when belonging to the stratified substances with which they are in contact. If instances of secondary and unstratified diallage rock did not exist, its analogy to hypersthene rock is so great, that such a fact would excite no surprise. It only remained to account for the Serpentine; and as I have shown it to be connected with trap, in the case of veins, the same rule might be extended to the masses in question. Thus the upper rocks of this series should be a secondary formation belonging to the trap family; the jasper being

formed from some argillo-arenaceous stratum, in the manner hereafter indicated in treating of that rock.

This view is now confirmed by facts occurring near Borghetto, at Monte ferrato, near Prato in Tuscany, and elsewhere; the defect of Brongniart's observations being corrected by others, who have shown that these overlying masses are partial, and are connected with deep-seated ones beneath, filling great rents in the primary strata, while the diallage rock, of various aspects, often includes masses of serpentine, together with those botryoidal siliceous schists so frequent in the vicinity of trap. There can therefore remain no doubt that there are veins of serpentine, and that both serpentine and diallage rock thus bear the analogy to trap which I have here suggested. And the confirmation is rendered complete, by the further remark, that the neighbouring schists have been indurated, that the sandy marls have become jaspideous substances, as in the junction with trap and granite, and that both the diallage rock and serpentine are found in the form of veins and of nodules, mutually imbedded or traversing.

With all these facts, (and more do not seem necessary,) the theory of Serpentine now becomes sufficiently easy; it being explained how it is stratified, unstratified, and venous, and how it occurs in both classes. There is no instance where a rock stratified from water, however subsequently changed by heat, forms veins, as, in fact, it could not, from the very nature of a vein. Serpentine is not, therefore, in every case, an aquatic stratum, nor can it be, in every one, a fluid intruding rock, like trap and granite. It is both; thus leaving to geologists the choice of its place, as I already said. When truly stratified, not in pseudo-strata, as in Brongniart's case, it must be compared with gneiss, as an aquatic stratum changed by heat, finding

its analogy in the trap rocks which have been fused *in situ*. When in masses involved in strata, that analogy is found in the similar limestones. And as the fluid intruding trap of veins is in no wise different from that fused *in situ*, so is explained the mineral identity of serpentine in these different cases; while, of this condition, its connexion with, and transitions into trap, leave as little doubt as does the truly venous form. And thus also is explained its claim on both classes, and its decidedly independent connexion with each; being exactly what occurs in the porphyries. Had I ranked it with the unstratified substances rather than the stratified, I should be justified by the usage respecting trap, possessing, when *in situ*, the same double claims. It is evident that the presence of calcareous veins is no objection to these views, as they are of posterior and aqueous origin; while it confirms them to note, that the minerals which it contains, such as pyrope, diallage, and hornblende, are of igneous origin.

The magnetic influence of Serpentine has been noticed by Humboldt, as if it was a rare and peculiar phenomenon. But it is not thus limited; being very common in trap, occurring also in granite, and, as far as I have experienced, in almost every rock which contains iron in a certain form and quantity. In Unst, where the Chromat abounds in the Serpentine, this influence is easily explained. If these disturbances of the needle, produced by the proximity of certain rocks, have been observed, few have examined the quantity of the effect, or the positions of the poles and planes of no action. Nor, excepting Saussure, have Geologists remarked those deviations of the needle which are produced by large masses acting at greater distances; though they could scarcely be overlooked by any one, who, either from navigating by the needle near to land, or from habits

of magnetic investigation, has been accustomed to observe the variable nature and tendency of this force. The experiments of Saussure appear to have been forgotten; as those of Captain Flinders seem to have been equally neglected. That the amount of this magnetic deviation is often very considerable, but extremely various, I have ascertained on the Western coast of Scotland; but it is a subject which, beyond this passing notice, is not within the limit of this work.

Serpentine is a simple rock, essentially; though there are varieties, of a compound character, independently of the numerous ostensible ones resulting from the colours for which it is so noted. But, for all this, it is best, as usual, to refer to that grammar of geology so often here quoted. There is little opportunity, from this country, to learn what features a territory derives from it, or what are the resulting soils. The cliffs of the Lizard are bold, broken, and picturesque, but the land is without any marked character; and the same is true in Unst and Fetlar. Of the soils of these tracts, it is difficult to give any general character. Yet every where in Shetland, except where limestone and serpentine exist, the rocks are deeply covered with peat; while, if occasionally found on limestone, it never occurs on the Serpentine, though the neighbouring tracts of gneiss and the other schistose rocks, are covered with it. Still, that soil is not uniform; since, while covered with verdure, in some places, it exhibits, in others, an arid brown desert of earth and loose stones. The climate of Shetland does not permit us to know whether even that soil might not, under better skies, be adapted to cultivation: at the Lizard, the serpentine district is favourable to the growth of wheat. It must be added, that in this country, at least, Serpentine resists decomposition, no less than disintegra-

tion, in an eminent degree. The shallowness of its soil marks the difficulty with which it is converted into earth; and the formidable cliffs and rugged points which it advances into the ocean, prove the efficacy with which it opposes the powers that demolish the neighbouring rocks and corrode the adjoining shores.

The association of Chromat of Iron with Serpentine is a remarkable peculiarity in its mineral history; but it has not hitherto been found a repository of other metallic veins. In the arts, it has been long known as an ornamental substance; and the value arising from its beauty and variety, is enhanced by the facility with which it is wrought and polished. As a building stone, it deserves additional attention, from its strength and indestructibility; though never yet sought after for that purpose. Many varieties also resist the fire in a remarkable degree; a circumstance also which should render it a greater object of œconomical attention than it ever yet has been.

CHAP. XXXIII.

Limestone.—Primary.

There is one familiar character by which this rock is distinguished from all others, but there is none by which those of the primary and secondary classes can be discriminated, when removed from their affinities in nature. It has indeed been said that distinctions might be found in their texture or composition, and in the presence or absence of organized bodies. But, out of a mass of facts by which this assertion is disproved, the following will suffice.

Primary limestone, lying under gneiss, in Sutherland, contains bituminous beds; and the older limestones associated with argillaceous schist, thence called *transition* rocks, contain organic fossils. Secondary limestones are so often deficient in these remains, that it is unnecessary to name examples. Primary limestone is not necessarily crystalline, since it contains earthy and compact beds, in innumerable places. Secondary crystalline limestone, on the other hand, occurs in the Isle of Mann, among earthy ones containing organic remains, and also in Sky, where it is frequently of a snow white, and undistinguishable from statuary marble. This important observation in geological philosophy, originally made by myself, has since been confirmed in various parts of Europe. But, in reality, the fact is sufficiently common in other situations; as crystalline limestone also occurs not unfrequently near the contact of trap. There is therefore no permanent or necessary mineral distinction; though, in particular instances, there are often very strong ones: while these remarks will serve to warn the student against pronouncing on the pri-

mary or secondary nature of a calcareous rock, from a detached specimen.

It has often been agitated whether all limestones had or had not originated in organized substances. That question has already been considered in the twelfth chapter; and it is probable that many of the primary limestones have once contained organic remains, like the secondary, even where these can no longer be detected. In Airdnamurchan, facts similar to those in Sky and Mann occur under some variation; conchiferous strata being converted into crystalline limestone or chert, according to their previous characters, with the disappearance of their organic bodies, at the places where trap overlies or intersects them, and no where else. In these cases, therefore, the influence of trap, under different modes, has not only caused a secondary limestone to assume the crystalline texture, but obliterated the forms of the beds, while the organic bodies have disappeared. The instance from the Isle of Mann, especially, seems to prove that they had been combined with the mass of the rock by fusion; and, that this is a process of fusion, is proved by the analogous effects produced on chalk by the passage of trap veins: while, though no large mass of trap is found in the Isle of Mann, to account for the appearances, the numerous veins offer sufficient evidence of former bodies of that rock which have been destroyed in the progress of time. The case of Airdnamurchan is peculiarly explicit. But it is here almost superfluous to repeat, that the influence of granite, of gneiss, or of other rocks which have been under the action of heat, may have equally caused the obliteration of the organic remains where they chanced to exist; producing also the crystalline texture common in these limestones. And that this actually does occur, is proved by the

fact at Cearp in the Pyrenees, elsewhere noticed, where the shells become gradually obliterated, with the corresponding acquisition of a crystalline texture in the rock, where it is in contact with granite. The bituminous strata in primary limestone, just noticed, may serve to confirm the same views; since, it is unquestioned, that in the secondary limestones, this character is derived from organic bodies.

As limestone occurs in every situation, from the most antient of the primary to the most recent of the secondary, and even of the tertiary strata, it must be considered the most universal rock in nature. At the same time, it presents fewer differences of character, if we except the adventitious imbedded bodies, than any other: a consequence arising from that comparative simplicity and chemical composition under which it has evaded that action of heat which has changed the characters of the other primary strata.

Primary limestone occurs in this country in masses so small that they can give no character to a district; and there is no reason to believe that it is more abundant in other parts of the world. This has indeed been often asserted; but, doubting the accuracy of that opinion, I must refer the student to the works in question; cautioning him to bear in mind, that no limestone can be deemed primary, from any thing short of a clear proof that it alternates with primary strata.

In the larger, as in the smaller portions, Primary limestone is disposed in beds, like the rocks which it accompanies; but these are sometimes so obscure that their stratification can scarcely be traced: a consequence, probably, of the fusibility of this rock, and of the influence to which it has in these cases been subjected. In the only manner in which it is known in

this, and probably in any country, in a regularly stratified disposition, it forms either a limited series of beds, alternating with one or more of the various strata, or else occurs in single ones of very small extent: while, in other cases, and more rarely, it consists of irregular nodules of different sizes, possessing no marks of stratification.

The larger collections of beds preserve the usual parallelism to the surrounding strata; being sometimes repeated in succession, at others, alternating with smaller or larger strata of the accompanying rocks. The smaller beds rarely continue for any considerable space; being extenuated till they vanish, after a short course; while often consisting of little more than a single thin stratum, or of a few detached ones, alternating with the including rock. In either case, they sometimes occupy a considerable space according to their breadth, without being far prolonged lengthwise; thus forming irregular insulated tracts. Not unfrequently also they vanish and again appear, even at distances of many miles, with unaltered characters, and accompanied by the same strata; as happens, remarkably, in that long range in which the limestone of Glen Tilt is comprised. In these cases, when the angles of elevation are also high, they display that character of far prolonged and narrow lines, to which the term vein has, not unnaturally, been applied by the people. The nodules or masses which possess no marks of stratification, rarely attain a dimension exceeding a few hundred yards; and this particular mode of disposition occurs most frequently in association with gneiss.

Primary limestone accompanies every rock, and alternates with every member of the associated strata; nor does it appear, in this country, to be peculiarly

attached to any one of the whole class. It is found in contact with granite in Glen Tilt; being penetrated, like the accompanying strata, by its veins, and presenting consequent changes of character, like those which secondary limestone undergoes when penetrated by trap veins. These consist in the loss of the stratified structure, in the intermixture of the accompanying substances, and in a great increase of hardness, attended by a change in the chemical composition. When found in gneiss, in the form of nodules, it is often also penetrated by the same granite veins which intersect that rock; and, in these cases also, it undergoes corresponding alterations of character. It is also not unusually found in gneiss, in the stratified form; as well as in quartz rock and in micaceous schist. When interstratified with the latter, or with schistose gneiss, it is sometimes so interlaminated with mica as to have been mistaken for these substances by geologists of considerable experience. Rannoch, and Blair in Atholl contain very remarkable examples of these varieties. It is occasionally also found in contact with hornblende and with actinolite schists; and, in these cases, it becomes intermingled with those minerals, particularly at the planes of contact. It occurs frequently in argillaceous schist, and principally with the fine clay-slate; either forming masses of considerable extent, or accidental laminæ. In these examples also, it is often so minutely interlaminated with that rock as only to be distinguished on the cross fracture; the laminar one discovering the schist alone with which it is interleaved. It has elsewhere been shown to accompany chlorite schist in the chlorite series.

From this enumeration it follows, that instead of occupying any determined place in the order of nature, it is perhaps the most irregular of the whole in its

associations; appearing to be peculiarly attached to no rock, whereas there is a predominant, though not a constant, affinity and order, among many others of the primary strata.

It is almost unnecessary to say, that it presents many varieties of texture, from the large crystalline to the most minute saccharine grain, and from a smooth and flat conchoidal fracture, to one of an earthy and dull aspect. It often differs from the secondary, in containing various imbedded minerals; though not so often as to form a sure ground of distinction. These will be found enumerated in the Classification of Rocks: while their existence proves, demonstrably, that the strata in question have been fused; giving occasion, as in micaceous schist, to the crystallization of similar igneous minerals. Its well-known chemical properties render a definition superfluous: but the student must recollect, that the indurated kinds do not readily effervesce unless previously powdered.

If it is superfluous to mention its œconomical uses, yet, as it often contains alternating laminæ of other rocks, so as not to burn readily into lime, it is often neglected, even when fit for all the purposes of masonry or agriculture. Being a limited rock, it is not very productive of metallic veins; but it is said that lead, manganese, silver, zinc, and gold, have been found in it. How widely it is used as marble, I need not say; while its ornamental varieties are amply recorded.

CHAP. XXXIV.

Lowest, or Old Red, Sandstone.

It is difficult to discover the exact natures of the red sandstones described by authors, and consequently, to adopt their observations, so as to illustrate the history of this rock as it occurs in our own country. The two distinctions relied on for discriminating it, are its colour, and its position towards the primary; being the first of the secondary strata, and immediately in contact with these. Hence it has been called the *old* red sandstone. But as I have shown that there is a primary red sandstone, the descriptions of authors have possibly been sometimes derived from it instead of from this rock. And as the red marl has been actually confounded with the present, the sources of confusion respecting its characters and connexions are obvious.

The mere fact of contact with the primary strata, is not an infallible criterion by which to distinguish the lowest secondary one, as I have formerly shown. Therefore, although the red marl occupies a position distant from this in the order of succession, it may come into contact with these, and thus be confounded with the present deposit, as it has been by Werner and his followers. Nor is the red colour an invariable characteristic of this rock; since it is occasionally grey, and also white, even in one bed; proving, that this does not form a geological distinction. Hence the geologist must not conclude that every red sandstone in contact with the primary rocks, belongs to this one; while, as the different strata in nature are rather analogous than identical, serious differences may exist in the constitution of this deposit in different countries,

even where the geological analogies are unquestionable. It is therefore his duty to study these differences, without allowing himself to be misled by hypothetical identities. Time will thus produce a more perfect history of this rock; while I can now only describe its characters as they have fallen under my own inspection. To borrow from other observations, would but incur the risk of confirming the present confusion; while an apparent path is often willingly trod till it is beaten, even where it misleads.

If it is not always possible to distinguish these three red sandstones, except by careful geological investigations, since the mineral distinctions give but limited assistance, the alternation of the primary sandstone with gneiss or other primary strata, is an infallible geological criterion for that rock. With respect to the red marl, the presence of salt is equally infallible; as that of gypsum is a good test, if not absolute. Its superiority to the coal series is another, as is its immediate inferiority to the Lias limestone. Although the old red sandstone is sometimes sufficiently distinct from this in mineral characters, it is not always so; and I do not therefore offer it to the student, to whom the more infallible test of its geological connexions is recommended.

The sandstone under review appears to be one of the most generally diffused rocks in nature; and may thus be considered, like gneiss, among the deposits commonly called universal. Occupying extensive spaces, it also forms masses of considerable thickness, producing mountains of conspicuous elevation. Foula, in Shetland, attains to the height of 1400 or 1500 feet; Kea cloch in Rossshire to nearly 4000. It is so uncertain, however, whether many of the foreign examples belong to this or to the red marl, that I dare not quote them

for the purpose of illustrating its general features. Such mountains rarely present a rugged outline, and seldom display the naked rock, except in their torrents and sea cliffs; as in those of Shetland, Orkney, and Caithness. Such is its general facility of decomposition, that the inclined surfaces soon become covered with rubbish, and, finally, with vegetation; while the cliffs and ravines, from their perpendicular nature and the frequently low angles of the strata, long preserve their original forms, so as to produce a well-known peculiarity of character.

An exception however occurs in the case of the conglomerate beds, which, from being of a harder texture than the finer sandstone, often remain after the softer parts have mouldered away; sometimes presenting insulated masses with vertical faces, or rising into the more fantastic shapes of pinnacles and towers; as, very notedly, in Montserrat. On Kea cloch, the finer sandstone also produces a serrated outline, resembling that of granite, from the same cause. The softer kinds are often deeply covered by alluvia, displaying the gradual progress of decomposition, from the solid rock to the loose red clay; while the rock often disappears entirely, as in Arran and Cantyre; the depth and colour of the soil alone remaining to mark its former situation.

The soil which covers the red sandstone is extremely variable; from the various proportions of clay, and sometimes of calcareous earth, which enter into it, or from the presence of argillaceous and marly beds. In the central districts of Scotland, there is often an adventitious soil upon it, the produce of former masses of Trap; and hence is explained the diversity of aspect which these districts present, from the most fertile to the most worthless. In Shetland, where this sand-

stone is as compact and pure as quartz rock, the land is often as barren as upon this worst of all subsoils.

The position of the strata presents every possible variety; being nearly horizontal in Orkney, in Caithness, and in many parts of the middle and southern districts of Scotland; while, in other places, it occupies every angle between the horizontal and the vertical, as may be seen on the southern boundary of the Highlands, in Invernessshire, and in Shetland. In Arran, the beds are bent into convex forms or more complicated curves; while examples of simple curvatures, or of more extensive undulations, occur in numerous other places. The tendency of the dip is extremely uncertain; respecting, in some place or other, every point of the compass; while the general north-easterly direction of the primary strata of Scotland, ceases to be traced in this one.

Though an unconformable position to the primary strata has often been held a necessary character of the secondary, this rock is conformable to the conterminous ones, at many points on the southern boundary of the Highlands and in Arran. The examples of reverse position are too numerous to require specification. There is indeed no reason why it should not lie in every possible position with respect to these; as formerly indicated, when treating of this subject. In Shetland and other places, there occur instructive examples of the mode of junction between the superincumbent sandstone and the primary rocks; the cavities in the irregular surfaces of the inferior set being filled with a conglomerate, without marks of stratification, and resembling an accidental heap of rubbish, which, as it proceeds upwards, gradually assumes the stratified character; till a regular series of strata is the result; while they become unconformable to the

primary ones in some places, and conformable in others; as the varying positions of these determine those two relations.

In its depth, this rock presents an infinite variety; the mass of strata being either originally thin, or else attenuated in some places, till it disappears, while in others, it amounts to many hundred yards in thickness. This attenuation might be presumed from general experience and principles, were there no evidence of it; since the persistence of strata is imaginary, and all have their limits; disappearing in their lateral progress, sometimes not to recur again for a considerable space.

If examples of these variations are required, Loch Greinord presents a case where this sandstone nearly disappears between the gneiss and the superincumbent strata; as instances of the reverse are seen in Arran, Caithness, Shetland, Rossshire, &c., where they range from some hundreds to three thousand feet, or more, in thickness. The dimensions of the individual strata are also various; the conglomerate beds being commonly the thickest, as the fine ones are the reverse; though the former are sometimes divided into distinct strata by finer sandstones. When not thus separated, as is most common, they often attain the depth of a hundred feet or upwards, without a division; while the fine sandstones vary from a few yards to as many feet, and even to less than an inch in thickness; when they consequently assume a schistose character. In these cases, the divisions of the beds sometimes result from a change of texture or composition, at others, from the intervention of mica, or clays of different characters, or shales, or argillo-calcareous compounds.

Viewing this sandstone as a single geological deposit, or group, extending from the primary strata to

the mountain limestone, it includes other substances inferior in quantity, and irregular in their recurrence. The chief of these are argillaceous schists, though considered as shales under the adopted classification. These are sometimes undistinguishable from the primary graywacke schists, when separated from their connexions, while, at others, they are mixed with the ordinary materials of the sandstone, so as to present transitions into it. In other cases again, they are as fine and compact as the primary slates; occasionally resembling even the green chloritic varieties. Lastly, beds resembling the ordinary shales of the upper strata, occur also in this deposit; being simply argillaceous, or argillo-calcareous, or so charged with iron as to be red or yellow, and thus finally passing into argillaceous ironstone. Beds of limestone are sometimes also contained in the red sandstone, though seldom extensive, and rather forming irregular masses or limited strata than continuous alternations. At times, they are mixed with the fragments of the surrounding conglomerate, at others divided by laminæ of shale, and contaminated with clay, siliceous matter, and oxydes of iron; occasionally also containing organic remains. Coal also occurs in it, as elsewhere noticed, though rarely, and seldom in any quantity; yet so as to be occasionally wrought in a limited manner in Scotland. But in reading such reports, let the geologist not forget how often the red marl has been confounded with it.

I must now point it out as a general fact in my experience, and, as I hope to show, an important one, that wherever this sandstone is highly indurated, its shales, whether fine or coarse, are identical with the primary schists, and that the argillaceous beds among the softer ones resemble the shales and clays of the

upper sandstones. And it is a connected fact, leading to a similar inference, that the indurated beds occur in the vicinity of the primary rocks, and more particularly in that of gneiss or the other older strata, as the less compact ones are found in the reverse situations. And of all these argillaceous beds I must remark, that they are commonly so inferior in quantity to the sandstone that they may be called subordinate, though Orkney produces a notable exception.

The frequent confusion produced respecting this sandstone, by the adoption of the term Red, obliges me to notice what I have seldom done respecting rocks. It occurs of all hues, from nearly perfect white to dark grey, and also of yellowish tints, independently of its various tones of red; while it is further often mottled and spotted with red and white, so as to have been thence mistaken for the red marl sandstone, by those to whom the term *variegated* constituted knowledge. Thus have many of these, especially when incompact, and when occupying large tracts, as they often do, been mistaken for other and superior sandstones; as have the hard kinds, lying near the primary strata, for quartz rock, from which, in detached specimens, they are in reality undistinguishable. I may also repeat, that the hard and grey varieties sometimes become yellow and tender, even to a great depth and extent, by a decomposition *in situ*, as in Orkney, so as to have led to similar false inferences. Let the geologist ever remember that it is his business to trace geological connexions before he determines geological characters.

The last circumstance in the history of this sandstone, relates to the rocks with which it is conterminous, and is necessarily dependent on the number of members in the inferior series, and on the order in which these are placed. The contact with coarse, or

graywacke schist is too common to render any examples necessary; as that with the finer schists must needs be so, where these are intermixed, while occurring also where fine clay-slate occupies large independent tracts, as near Oban and elsewhere. It succeeds micaceous schist, necessarily, on the southern border of the Highlands, because this rock is often, here, the last of the primary series; while this remark includes the associated chlorite and talcose schists. But I must observe, that at this contact, in some places, the micaceous schist passes by an apparently regular gradation into the sandstone, through a conglomerate, formed of its fragments and becoming gradually red; while the conformability of the two rocks in some places, has led incorrect observers to say that there was no distinction between the primary and secondary classes. It reposes on gneiss very widely in Scotland; and here also the union is often such, that an actual transition between the two rocks has been imagined by similar observers. A more interesting case of its connexion is that with granite, conspicuously displayed, among other places, near the Ord of Caithness. And it is worthy of notice, that at the junction in this place, it is often difficult to distinguish between the two; so perfect is the union, and so nearly alike are the mineral characters. The ingredients of the sandstone, at the contact, consisting of granitic fragments, are so compacted, and in some places, so blended with the granite, that a common eye might easily confound them, and a hypothetical geologist consider this a true gradation between these rocks; especially as the lowest strata of shale and sandstone also, are so united with the granite as to give the fallacious appearance of continuity. If I have not hitherto observed the sequences of this sandstone to quartz rock, it must be from want

of opportunity; since the alternations of this rock with gneiss and micaceous schist render that a matter of course, should it occur in such a place. And if also I have seen no instances of its junction with primary limestone, the rarity of this rock equally explains an exception which can be only apparent.

The strata which succeed to the red sandstone must needs be various; from the different successions of those in different countries, from their variations in number and quality, and from that extenuation through which, even in a considerable series, the upper sometimes repose on the boundaries of the containing cavity. Yet as the "mountain limestone" is conspicuously the next stratum in England, while sufficiently constant in Scotland, and as an analogous one is similarly found on the continent, this must be esteemed the natural succession. Yet that any superior beds may follow it, to the exclusion of this limestone, and more, is evidenced in Scotland, where, in different places, it is succeeded by the coal strata, by the red marl, by the lias and oolithe, and by the green sand deposit.

As this sandstone is composed of the fragments of previous rocks, every antecedent substance is found to aid in its formation; including, with granite and the primary strata, the trap rocks of a more antient date: while I need only add that as the conglomerate and coarser beds contain fragments of rocks, and the more conspicuous minerals of these, quartz and felspar, so the finer are the produce of sand or of sand and clay, with, more rarely, mica and calcareous matter. All these substances however are not every where contained in this rock; which, on the contrary, in different places, presents great diversities of composition. These variations are matters of interest, independently of the merely mineral differences; since they are connected

with the history of its geological origin. As far as it is safe to generalize from a few facts, the number and species of the ingredients depend on those of the nearest primary rocks; though this rule is attended by many exceptions. Yet the places where it does hold good, justify the inference, that in these at least, the materials have not undergone any very distant transportation. That they have sometimes experienced this, is unquestionable; as is proved by a composition less coincident with that which might thus be inferred, and by the form of the materials. Organic remains are rare in this sandstone; but terebratulæ, madrepories, trochites, and others have been observed, as formerly mentioned.

There are two modifications of the form of the materials, where of a certain size; being either angular, or rounded, and these marking respectively, the quantity of motion they have undergone before their consolidation. The rounded form does not, however, by itself, imply a distant transportation, as the long continued action of water will answer all the requisite conditions. Examples of this occur near Oban; where this form is united to a peculiarity of composition marking an origin from rocks at no great distance. Occasionally the size of the fragments is such as to amount to three or four tons in weight; but, more commonly, they do not exceed a few pounds, descending to the finest sand, which is indeed the predominant form of the fragments; as the fine sandstones far exceed the conglomerates, thus giving a name to the whole. I need scarcely say, that fragments of all sizes occur in the same rock, and that a portion of fine sand is essential to the structure of every variety. As to the relative position of the finer and coarser strata in any given deposit, there is no absolute rule, though it is far

most common for the conglomerate to be the lowest: being sometimes however uppermost, while they also occasionally alternate, through a whole deposit, and further, sometimes occupy different parts of the same bed, which thus undergoes a lateral change of texture. Single fragments of large size occasionally also intrude; and the presence of rounded masses does not exclude that of angular ones, as the two sometimes occur together. In the conglomerates as in the sandstones, the induration is so various that the fragments seem at times to be barely in contact: whence the mass is easily disintegrated by a slight force, or by the weather; while, at others, they are cemented by indurated clay, sometimes with calcareous carbonat, or by crystalline quartz, so as to present every degree of induration: often emulating that of quartz rock, when fine, and of granite, when coarse; and also presenting, in the former case, similar compact, uniform, and splintery fractures. And, respecting the structure, I must also observe, that a cuboidal or analogous division of the strata often confers on this sandstone the physiognomy of granite, when the angles have been rounded by exposure to the weather.

If the theory of this deposit, so important in the philosophy of geology, ought now to be apparent, it requires a few additional words; since geologists have mistaken more than one essential point respecting it. That it has often been a deposit beneath water, formed in the same manner as the later sandstones, is obvious; but the facts will not allow me to admit that every example, or all the parts of any one, have been produced in this simple and gradual manner. The enormous masses of the conglomerates, with their peculiar internal characters, their uncertain and often singular positions, their repetitions, and other circum-

stances which I hope I need not now dwell on, to a reader who has mastered the principles and the facts of this book, indicate tumultuary depositions, as well as gradual ones, and even repetitions of these, dependent probably on torrents resulting from antient displacements of the strata. And it is also quite conceivable that terrestrial alluvia should have been consolidated into such rocks on the surface of the land of those periods; affording a further explanation of the peculiar forms of many of the conglomerate deposits, and of the absence of stratification in them.

And if such terrestrial consolidation might occur from water and repose, so might it also from the action of heat, of which there is abundant evidence from the facts already stated; constituting another important feature in its theory. These are, its union, amounting to nearly fusion, with granite, gneiss, and micaceous schist: to which may be added that peculiar compactness in itself and in its shales, which occurs in the vicinity of these rocks, disappearing in the more remote and generally finer strata. Thus, like gneiss and micaceous schist, it has suffered the influence of heat when near rocks which are proved to have undergone this; as, in other places and portions, it is a merely aqueous rock, like the later sandstones. And thus are dismissed, or reconciled, if the reader prefers this term, the rival hypotheses of the ultra-igneous and ultra-aqueous sectaries. I trust that I need not now bring this view minutely to bear on the antient condition and changes of the primary strata, nor on the relations which it possesses to organic fossils. A system of philosophy which trusts nothing to the reasoning of its readers, will not make many philosophers.

CHAP. XXXV.

Upper Sandstones.

THE peculiarity and importance of the preceding sandstone induced me to give it a separate place; but in this division are included all the others, which follow, of whatever character, or however technically or locally distinguished. It is impossible to discriminate them all as rocks, whatever may be their geological positions or associations: while such an attempt would lead to wearisome repetitions; since even the recorded deposits consist of a very limited number of materials, disposed in a similar manner. Even those which are most interesting, from their geological associations or from their uses in the arts, possess no distinctions as mineral compounds, or are distinguished by characters too vague to be described in words.

An attempt moreover to describe accurately the several geological connexions in which the rocks of this division exist, would lead to geological histories of the whole series of the secondary strata in every part of the world; a subject which, were it even understood, would be beyond the limits of this work. They occur through the whole range, from the lowest red sandstone upwards; and, under these several situations, not often presenting any very decided differences of character. Their chief distinctions are indeed derived from the peculiar groups or associations in which they are found in some particular country; constituting those different series which have been distinguished by the term *formations*. These groups appear to have been investigated, in England, and generally perhaps in Europe, with considerable accuracy: but it remains doubtful whether some of these associations are not

local; nor have we a sufficient number of analogous accurate observations from other parts of the world, to justify any more extensive generalization.

All that I can here pretend to do, is to give a general account of those deposits which seem most uniform and extended, and which, from possessing certain marked characters where they occur, have obtained particular names. Those which belong to none of these groups or deposits, must unavoidably be neglected, as suited only to the topographical descriptions of countries or tracts; and it will be here sufficient to remark, that they are found, not only in every part of the secondary series, as inferior or subordinate members of calcareous deposits, or as casual substances among anomalous strata of clay, shale, and marl, but among the tertiary also. The general theory of such deposits has already been explained.

After the old red sandstone, the first important one is that which forms so large a portion of the coal series, and the next is the red marl of England, succeeding to the magnesian limestone. On the Continent, the quadersandstein appears also to claim a rank here, being separated from the red marl by the muschelkalk; and lastly comes the green sand, immediately inferior to the chalk, and above the oolithe limestones. If the ferruginous sand of England is to be distinguished from this, it must be added to the list, as intermediate between the latter and the oolithes.

The sandstones of the coal strata often extend to an enormous thickness, both in the total mass and in the individual beds. They are the proper repositories of the coal beds with which they alternate, while they also are interstratified with limestone, and with shales and clays, sometimes containing nodules and beds of ironstone. They are occasionally of a coarse or con-

glomerate structure in the lower beds, thus forming the "millstone grit" of England, but the more prevailing textures are fine. They are often exceedingly pure and white, offering the most beautiful of building materials, yet varying much in compactness; while, in other cases, they are argillaceous, calcareous, or ferruginous, presenting corresponding diversities of appearance, with many different colours, though red tints are comparatively rare. When impregnated with bituminous or carbonaceous matters, they are sometimes black, and they often contain fragments of charcoal or lignite. The very few organic remains found in this series belong almost exclusively to fresh water or to the land; and the most remarkable are the vegetable fragments, particularly noticed under the history of coal, as the geological relations and characters of this sandstone are necessarily also noticed in the same chapter.

The next deposit is the Red marl, or the variegated sandstone of foreign writers, also called the New red sandstone, to distinguish it from that described in the former chapter; while I suppress other synonyms, connected with disputes now useless. This most important deposit claims a far higher rank than the preceding, which, as far as we yet know, is comparatively limited. It follows immediately on the magnesian limestone, and, in England, is succeeded by the lias and oolithe, though, on the continent, there are interposed the muschelkalk and the quadersandstein.

As a series, it presents a complication resembling that of all the arenaceous and calcareous deposits; including limestones, clays, marls, and shales. The beds are sometimes of a conglomerate structure, at others a fine sandstone, and occasionally schistose; and, in composition, the rock is calcareous, argillaceous,

or ferruginous, or all together, presenting endless variations of aspect and colour. If red hues prevail, it is sometimes also brown, yellowish, grey, greenish, and even white; and is often singularly striped and spotted with different colours, whence its name of variegated. We must be cautious, however, of deciding on the geological position of a sandstone from this circumstance, as has been often done; since I have shown that it occurs in the "old" red sandstone also. Further, it contains fetid and oolithic, as well as common limestones, in some places; though the minuter details must be sought in the numerous works of authors.

But that which especially distinguishes this deposit from all the secondary sandstones, is the presence of rock salt. If not thus absolutely limited, gypsum also occurs in it, so as to become another characteristic. But it is the proper, or even exclusive repository of salt, although that mineral occasionally passes beyond the rigid boundaries, on both sides, so as to appear in the magnesian limestone below it, and in the lias above; as noticed in the chapter on that substance.

With respect to its organic remains, their presence has sometimes been denied; but there seems no doubt of the fact as to the foreign examples. On the continent, there have been found remains of lacertæ and fishes, with gryphites, ammonites, and belemnites; while the vegetable fossils are said to amount to twenty or more, comprising equisetums and ferns, like the coal-strata, with some coniferous and liliaceous plants, as well as fuci in the lower portions; if indeed some or all of these do not rather belong to the strata in contact, with which it has been confounded, or to fresh water formations not sufficiently distinguished from it. In England, it has been said that no organic remains occur in the proper red marl.

The next most important circumstance relating to this series, is its universality, or rather, its great extent; as formerly noticed in the chapter on the Revolutions of the Globe. Added to this, is the general or frequent unconformable position which, jointly with the magnesian limestone, it holds to the secondary rocks beneath. The interest thus connected with its localities is considerable; and it is not a little remarkable that it is the only one of the secondary strata which has been traced with unquestionable characters in all quarters of the world. The marked nature of that character, in being the repository of the two mineral substances above-named, have indeed given it an advantage in this respect, which has not yet occurred in any other deposit. It is a means of identification afforded by nothing else: while the limitation and the peculiarity both, bespeak some universal, or very wide condition of the Earth's surface at the period of its deposition, to which we as yet know of no parallel unable as we may be to conjecture its nature.

Not to detail localities more minutely than a work of this nature well admits, it abounds in England, as also in France, Switzerland, Germany, Poland, Spain, and Italy, being, indeed, generally extended over the European continent. It is a remarkable fact, however, if true, that, in the former countries, it contains no salt to the south of the Alps. If we proceed into Asia, it is found, extending, from Riga, to the Ural chain, abounding between the Ural river and the Wolga, reaching to the Caspian, and thence spreading far and wide into all the neighbouring countries; being found in Asia Minor, as well as in Persia, Tartary, India, and China.

This stratum abounds, indeed, all over Asia; and he who desires to trace its extent, may apparently do

it with safety, by examining the sandy deserts on a map; since, wherever these have been described by travellers, it is invariably found that salt occurs in them. There seems no reason to doubt that all the sandy deserts of the world belong to this stratum; and hence the salt pools and the brackish water that make so conspicuous a figure in the narrations of travellers. I may name, out of many, the salt range of hills crossing the Indus at Karrabah, and extending to Jellapoor, the desert of salt between Taheran and Ispahan, that which extends from the Heirmund river in Seistan to the range which divides that province from lower Mekran, of four hundred miles in length, and another, of equal dimensions, which reaches from Koom and Kashan, to the provinces of Mazandaran and Khorasan. But the most singular tract of it, hitherto undescribed, is found occupying the shores of the Persian Gulf in the neighbourhood of Ormuz, not less remarkable for its immense thickness, than for its configuration and colour. It is presumed to be this deposit, from the gypsum and salt which it contains, and from its connexion with the sandy and salt deserts; while the visible depth in the vertical cliffs exceeds four thousand feet, and the beds are divided into columns grouped into castellated and architectural forms, the whole mass being of a pure white colour, and the general effects singularly magnificent and picturesque.

The accounts of all travellers decide its presence in Africa, where gypsum and salt both abound; and here also we shall probably form a correct conclusion, in considering the sandy deserts of this quarter of the world as appertaining to the same rock. If America has been yet but partially explored, the existence of the same rock is ascertained in the territories of Hudson's Bay, and in the great plain of the Missisipi,

extending thence into Louisiana and Mexico. Thus also it must occur near the Oroonoko; since the red colour of the Rio del Norte and the Rio Colorado, together with the salt of the plains through which they flow, bespeaks its presence. When Ulloa mentions the existence of salt at an elevation of ten thousand feet in Peru, we may also conclude that it is present there. Lastly, it has been observed in various places in New Holland.

Though the Quadersandstein is unknown in England, it is too important an object in the estimation of the Continent, not to deserve a place here. This mass of beds is separated from the red marl by a limestone, the muschelkalk, not admitted into the English series, and it is consequently followed by the lias. Yet there are continental geologists who affirm that its essential place is between the lias and the oolithe, and that the beds occurring beneath the former limestone are comparatively unimportant. If, again, a quadersandstein occurs above the oolithe, we must suffer Germany and England to settle whether there shall be two quadersandsteins, or whether the superior one shall be called a modification in the greensand. In all this I can see only disputes about terms; as I regret to see Geology thus occupied. A sandstone with the distinctive characters of this German one may occur in any part of the series; and why must I ever repeat, that unless all the strata of the earth had been showered down from the clouds, they could not have possessed these fancied correspondences in distant countries? La Place determines that the ring of Saturn must rotate with a given velocity, or that it could not exist. Mathematicians would believe in this rotation though they had never seen it; but had they philosophized as geologists do, they would have been content

to believe this ring at rest, because they did not seek after the causes of its figure, or else, even when these were assigned, have maintained that it was so. Do the latter profess their contempt of the rules of philosophizing, or do they confess their ignorance of those rules? The dilemma is before them, to choose.

Be this as it may, the lowest sandstone of this name reposes on the muschelkalk in many places, as at Helmstadt, near Schweinfurt, &c. and when this is absent, as it is to the north of the Hartz, it is found in contact with the red marl. In Bohemia it lies on the coal series. As we cannot refuse our assent to facts so detailed and so precise as those which relate to this sandstone, it adds confirmation to the opinion that the deposits of secondary strata are analagous rather than identical, and have been produced under different circumstances, in different original cavities or seas.

The Quadersandstein is described as generally fine, and as whitish, yellow, brown, and reddish, consisting of rounded quartz with occasional mica, and with an argillaceous or argillo-ferruginous cement; sometimes also containing calcareous crystals and veins of quartz. It is occasionally decomposed into extensive tracts of sand, as in Bohemia; and it contains few "subordinate" beds; these being conglomerates of quartz pebbles, or marls, or argillaceous strata, including fragments of plants in the form of lignites; as it is sometimes also coloured grey by their fragments and fibres. The plants in question are thought to differ from those of the coal series, from which this rock differs so materially in age and position; yet to bear an affinity to palms, and to the lycopodiolithes of Schlotteim, comprising also carpolithes. The fossil shells are pectines, turbines, terebratulæ, gryphites,

belemnites, pinnites, and others. It is plain that the description given of the rock, or the series itself, might be that of any sandstone; but it is esteemed to be one of its distinguishing features, that it breaks and wears into singular squared forms; producing walls and spires and ridges, as between Blankenberg and Halberstadt, along the Elbe, at Goslar, and in other places.

Though uncertain whether the Ferruginous sand will remain a separate deposit in the opinions of gelogists, I may describe its characters in England. If it occurs on the continent, most observers there include it with the green sand. It succeeds to the oolithe limestone, and though partial, presents, in some places, beds of considerable thickness. It consists of sand and sandstone, commonly very ferruginons, and therefore generally brown, or yellow. Conglomerate beds occur in it, together with clay, marl, and fullers' earth. It sometimes contains hematite and ochre, with lignites of various character, and traces of ferns and other vegetable remains, which have deceived coal surveyors into the expectation of the true coal series. The fossil shells appear to be rare, but include nautilites, ammonites, belemnites, ostreæ, terebratulæ, and echini, with sponges and corallines.

The Green sand, which is the last and uppermost of the sandstones, lying immediately beneath the chalk, is a much more important deposit, since it occurs in abundance on the Continent of Europe, as well as in England; as also in France, in the Alps of Switzerland, in Savoy, in Germany, and elsewhere; often forming masses of great depth, as it does even in Scotland, where these upper strata are so rare. This also consists both of loose sand and of sandstone; and though the sand is siliceous, the cement is generally calcareous, while the calcareous matter also, sometimes

nearly excludes the quartz, producing limestones. The green colouring matter consists of small grains, sometimes extending to the chalk above, producing the chloritic chalk of the continent, and also to the strata beneath. It also contains mica, with beds of chert and veins of chalcedony, cherty flints, and beds of marl and of clay. Like all the other sandstones, it is occasionally a conglomerate. Though the characteristic colour is an obscure green, it is sometimes whitish, grey, yellowish, or brown. Crystals of quartz, and of calcareous spar, with pyrites and sulphate of barytes, also occur in it, with rare lignites and silicified wood.

The organic animal remains are very numerous. In the number of its alcyonia it approaches to the chalk, and it contains also many echini, with a few remains of corallines and encrinites, and of fishes' teeth. For these and its numerous shells, I shall however refer to the authors so well known.

On the sandstones which occur above the chalk, or in the tertiary formations, I need make no further remarks than those formerly given in the chapter on that subject; referring to the authors who have described these, for details not here admissible.

CHAP. XXXVI.

Secondary Limestones.

It was already remarked, that while these limestones occupy a considerable space in the secondary series, the waste of the previous rocks will account for the arenaceous and argillaceous strata which unite with them to form it, under the shape of sandstones and shales, but that in comparing the proportion of primary limestone with that of the secondary, the waste of the former rock could not have produced the enormous quantity of the latter. Another source was therefore to be sought, and that was shown to be the action of living animals.

As the primary limestones alternate with the other associated strata, throughout the whole series, so the secondary extend through the entire class to which they appertain. Occupying also considerable tracts on the surface, they form the basis of extensive plains, and constitute many remarkable ridges of hills throughout the world; thus ranging from the lowest situations, as in England, to very high elevations, as in Jura and the Apennine.

If even it were within my plan to describe the characters of every rock and every series, everywhere, it would have been difficult, or rather impossible, to have attained such an object; while, in the present case, this difficulty is particularly felt. Our accounts of the calcareous tracts of the earth are especially defective; while the term *transition*, with the mistaking of secondary for primary limestones, has produced great confusion. It is but recently that we have acquired definite ideas, even respecting those of Europe; and, to this hour, many of them are involved in ob-

scurity; while geologists have increased the difficulty, or rather, have created one, by attempting to find identities that have no existence. Nor is it part of this design to describe all the local variations of these rocks and deposits, even where best ascertained; to detail the successions and alternations of every bed of limestone that has been described. Such information belongs to topographical geology, not to a general view of the Science; while the enquiry would involve discussions respecting many hypothetical statements and analogies, better left in the hands of the great reformer, Time. There has been a peculiar temptation to extend analogies and identities in the case of these limestones; because, independently of their importance, it has been supposed that they could be identified, even in countries widely separated, through their organic fossils. I have shown, first *a priori*, and then by evidence, that this test was often fallacious or insufficient, and that the consequence must be error or fiction; while it is certain also, that many limestones are limited to particular districts. If there is any one especially extensive, it is the series which follows that very widely diffused deposit the red marl; and, in a certain sense perhaps, both these may be considered as general, but not " universal" deposits; though the latter prevails in many countries where the subsequent limestone does not exist. I shall therefore continue to limit myself to the most conspicuous calcareous deposits, and chiefly to examples from Britain; partly because they are best determined, and partly from their peculiar claims on a British writer: referring to authors for those details which transcend my limits; yet cautioning the student against the overweening of those who imagine that in describing the topography and details of the English

secondary strata, they are producing systems of Geology.

The secondary limestones of Europe are thought to be divisible into the following principal deposits; but it is as yet unsafe to extend these to other parts of the globe, while no philosophical Geologist can believe that even all those of Europe are understood. The antient geological travellers have not enabled us to profit by their observations; and when Klaproth, recently, describes primary limestone as occupying great spaces in Caucasus, we may safely conclude that he is in error.

The lowest of these is the "carboniferous" or "mountain" limestone, lying beneath the coal series; and the next is the "magnesian limestone" of our own country, above it, supposed to correspond to the alpine limestone to the first "flœtz limestone," and to the zechstein of the continent. Next comes the muschelkalk, thought to be unknown in England, followed, after an interval of sandstone, &c., by the lias, and then by the extensive oolithe series, supposed to correspond to the Jura limestone and other great deposits of Europe, and including what is called the Jura dolomite. Lastly comes the chalk, with its associated members. The limestones not considered principal, are found, first in the old red-sandstone, and more extensively in the coal deposit; after which they occur with the red marl and the other arenaceous strata, and further, in innumerable anomalous situations through the whole remainder of the series; sometimes acquiring, in England and elsewhere, local distinctions, which I can here rarely notice. In a similar manner, they form portions of the lacustral and analogous deposits.

The lowest, or "mountain" limestone, under various names, immediately follows the "old" red sandstone,

having been formerly considered a *transition* rock by foreign geologists. The beds are often of great thickness, and the series of considerable depth; yet at times, as in Scotland, the reverse; while they occasionally include thinner strata of clay, shale, and arenaceous rocks, which, in some places, becoming more prevalent, materially affect the calcareous character of this deposit. The limestone itself is sometimes pure, approaching to the crystalline texture; while, at others, it becomes argillaceous, magnesian, ferruginous, or bituminous, presenting also a great range of colour, through white, yellow, gray, red, and black. It sometimes contains nodules of a cherty flint, disposed like the flints of chalk, and is an occasional repository of lead, copper, zinc, and iron; including particularly, many lead mines in England.

The fossil remains belong chiefly to genera different from those of the upper limestone; rather bearing an affinity to those of the later primary rocks. Fragments of fishes have occurred, together with trilobites; while corallites and encrinites abound, as the swimming cellular shells are numerous: besides which, many bivalve and univalve genera, such as orthocera, nautilus, ammonites, melania, turbo, nerita, helix, modiola, mya, terebratula, cardium, and spirifer occur in England and elsewhere. Fourteen species of plants, consisting of equisetums, ferns, lycopodiums, and fuci, have also been observed; the former indicating that land in which the subsequent coal was produced, as the latter do the joint presence of the sea. In such a locality at least, this limestone was the mud of an æstuary; as has been the case with the lias and others following it. The last feature of this limestone which may be named, is the frequent occurrence of caverns, and of subterranean fissures often giving passage to rivers.

The Magnesian limestone, as the next in order, succeeds to the coal strata when these are present; while, in other cases, following the supposed *transition* class, it became the lowest member of the secondary series, or the first flœtz limestone of the German school, as already noticed. The presence of conglomerate beds consisting of fragments of the inferior limestone, is one of the most interesting features of this deposit; confirming the former remarks respecting the production of mixed rocks at the intervals of revolution among the strata. Thus the conglomerate, like the mountain limestone itself, is also occasionally cavernous.

The strata are of variable thickness, sometimes containing the usual associated substances; and occasionally including the gypsum and salt which belong, more properly, to the sandstone above it. The presence of magnesia, sometimes amounting to twenty per cent., is one of its most remarkable characters, though far from a constant one; while, as it occurs also in the mountain limestone, these deposits have occasionally been mistaken for each other. It is generally of a granular or sandy texture, becoming sometimes oolithic, and also cellular, while often, further, possessing a slight lustre; and the colours are commonly buff, passing into brownish and reddish tints; more rarely, white. It sometimes contains lead and iron. Organic remains are rare in this limestone; but fishes have occurred, together with entrochi, encrinites, flustræ, donax, arca, and anomia. If a Monitor has been found in "marl-slate" said to belong it, we may be allowed to doubt the accuracy of the observation. Eight fuci are named as having also occurred; adding however but a superfluous proof of that marine origin which every thing else indicates.

The Muschelkalk of the Germans is esteemed by

them a separate deposit, equally meriting attention; while, if sometimes said not to be ascertained in our own country, others associate it with the lias. Being above the red marl, it is sufficiently distinguished from the magnesian limestone; and being separated from the lias and oolithe by the quadersandstein, it must also be distinguished from these, if this arenaceous deposit merits a distinction. If English geologists have thus disputed respecting it, it is a consequence of that patriotism of geology which desires to reduce every country to the favoured model, as all opinions must conform to that of Self. Philosophical Geology, unable as yet to reconcile German Self and English Self, must submit to suspense till other countries have also advanced their respective strata, and respective claims to dictate; but it may, in the mean time, note these two deposits, in confirmation of what was formerly said respecting the imaginary wide identity of series among rocks.

This limestone occurs in the Alps and the North of Germany, where it is often much inclined; the strata being nearly vertical in the Zimmersberg. It is found near Berchtolsgaden, in the chain of the Gollinger Alp, in the Durrenberg, in the hills about the Königsee, and in the Tyrol near Hall. At Ebenau, where the red marl is wanting, it reposes on the magnesian limestone; exhibiting sections from 1000 to 2000 feet in depth: and, in most parts of the German Alps, it is covered by the green sand and chalk only. As it occurs also on the boundary of Styria, in the Carpathian mountains, in Hungary, and in Croatia, there can be no reason for refusing it the conspicuous place assigned to it among the secondary limestones.

It is generally granular, of a fine texture, and, more

rarely, oolithic. Occasionally, it is magnesian, or bituminous, and, in some places, resembles the English magnesian limestone. It presents all the usual colours; whitish, greys of various hues, and yellows, tending to reds and browns. Nodules of cherty flint and of pyrites occur in it, as do beds of marl. The fossils are, chiefly, encrinites, pecten, terebratula, ammonites, mytilus, turbo, astrea, echinus, tubipores, millepores, and alcyonia.

The next principal deposit of limestone upwards, is the Lias of England, separated from the last, as I have just remarked, by the quadersandstein, on the continent, but, with us, following the red marl. If it has sometimes been associated with the succeeding calcareous series, the oolithe, it seems most convenient to consider them as separate deposits. The total series is, properly, a collection of argillaceous beds containing limestone; the calcareous strata predominating in the inferior parts. These are commonly thin, and separated by clay and shale; being, in the upper portions, often interspersed through a blue marl. Such at least is a general character for the English examples; but, on the continent, it presents other variations which I need not detail. This limestone is generally distinguished by its very argillaceous character and aspect; being most commonly grey, of various tones, passing to white; while, from containing large portions of iron and clay, it is used for water cements.

If I already noticed some important inferences respecting former conditions of the Earth, to be derived from certain organic fossils in this series, I may here again suggest some striking resemblances between the Lias and the plastic clay, or the deposits immediately succeeding the chalk, as opening to observations

which may hereafter furnish us with more accurate grounds of reasoning respecting yet unsuspected changes in the earth's surface, during the deposition of the whole series from the magnesian limestone upwards; while, as far as the present facts go, I shall immediately attempt an enquiry into this neglected or forgotten subject. A future more accurate knowledge of the Lias, better reasoned on than it has yet been, may also ultimately throw light on the very singular circumstances attending the red marl. At present, I must suffer this hint to be pursued by future observers; but the organic remains which have led to it, are chiefly the vegetable ones and the Lacertæ, of which two have been termed Ichthyosaurus and Plesiosaurus. Turtles and fish also occur in the Lias, together with some crabs; and among other shells, the genera ammonites, nautilus, belemnites, scaphites, helicina, trochus, tornatella, melania, modiola, unio, cardita, terebratula, gryphæa, ostrea, pecten, echinus, with encrinites and corals, and vegetable remains including ferns and other terrestrial plants.

The Oolithe, here distinguished from the lias, is a term used to include the principal calcareous deposits of Europe; but, for the reasons so often assigned, we have no right to identify them with the limestones of other parts of the world. The great calcareous ridge of the Jura is ranked here: but I need not enumerate localities to be found in every geological work, whether as to this or the lias. English geologists have extended this term to the whole deposit, calcareous or otherwise, between the lias and the ferruginous sand; and thus, in England, it presents numerous calcareous strata, to many of which peculiar local names are applied, separated by beds of the several other substances which contribute to form the mass of the secondary

series. For these details and arrangements, which are in reality partial and topographic, I must unavoidably refer to themselves, and principally to Conybeare and Phillips.

Though beds, of the properly oolithic structure, occur in the whole of this series, it also presents, in colour, texture, and composition, examples of almost every variety of limestone. To enumerate these, would be a fruitless repetition; and to give the details, either of domestic or foreign examples, would exceed the limits of a systematical work. The organic remains are, equally, too numerous to be here quoted; while the mere enumeration would serve no purpose, unless they were severally appropriated to the beds which they are said to identify and discriminate, in our own country at least. The book just referred to will give what I need not reprint; noticing only, that with numerous genera of shells, they contain alcyonia, corals, encrinites, crustaceous animals, fragments of fishes and amphibia, together with many plants, and conspicuous deposits of lignite coal. It is said to have produced an Opossum in England; which can be no cause of surprise when it contains terrestrial plants, amounting, it is said, to more than twenty, and analogous to those of the coal series, since consisting of palms, ferns, equisetums, and lycopodiums. Yet it ought surely to be obvious, that when remote beds are said to be identified because their fossils are the same, the proposition is identical and nugatory; since it is simply to say, that similar fossils exist in two places. The comparison of two shells, which all can make, may prove those alike or different; but this is conchology, not geology.

The "Dolomite" of Jura, is said to appertain to this division; but this term having been applied to all

magnesian limestones, it is one of those pernicious ones which has produced considerable confusion; serving further, like others, in lieu of a description, while also appearing to involve knowledge unknown to others, and thus carrying the semblance of profundity. Thus also it has been used to distinguish those limestones, in whatever situation, which have undergone the influence of granite or trap; as if a mere term could be a substitute for a knowledge of the circumstances attending any rock. The science would make no small gain by rescinding this, and some others, from its catalogue of words.

The last limestone, as it is the uppermost of the secondary strata, is the Chalk; proceeding upwards, when complete, from the beds called chloritic chalk to chalk marl, and subsequently to hard and to soft chalk. In England, this deposit is very conspicuous, from its extent and purity; but, though far less considerable than the oolithe, it occurs also, if often with characters less marked, in various parts of Europe: as in Scania, Jutland, and Zealand, in France, extending through the Netherlands, in Poland, following the course of the Carpathians, in Bohemia, Galicia, and Silesia, in Italy, in Spain, and in the Ionian islands.

The collective beds are often of great depth, as in our own country; and the upper ones are noted for containing strata of flints, while the inferior are free from them, giving rise to corresponding distinctions. The accumulations of similar flints in particular places, seem to indicate the waste of an analogous including rock; denoting its former presence in places where it no longer exists, as in Scotland, in Guernsey, and in many parts of the continent. Beds of clay and of marl also occur in this deposit; the green earth which characterizes the chloritic chalk, being found chiefly in the

lower beds, which sometimes also pass into a compact limestone. Though white when pure, it is sometimes yellow, grey, and reddish, and occasionally contains magnesia, or clay, and more generally, sand.

The organic remains are numerous, and, like those of the inferior strata, belong to species, at least, which are supposed to be no longer existing. Some traces of fishes and of lacertæ have been found in it; but the most remarkable circumstance consists in the great quantity and variety of echinites which it contains. It is also noted for its sponges and alcyonia; containing moreover, encrinites, corals, and many genera of shells, for which I may refer to the same catalogues. Including the green sand with it, the vegetable fossils exceed fifty; of which, with some fuci, six are said to be coniferous, and two liliaceous plants, in addition to the genera usual in the coal strata. But when it is inferred that coniferous or liliaceous plants had never existed in former conditions of the earth, that new æras of creation are thus marked, and that the characters of the plants in former strata prove differences of temperature in the Earth at those periods, this is the ignorant and rash reasoning from negative evidence which I hope I have sufficiently exposed on former occasions.

Such are the leading divisions of the secondary limestones; and there is nothing here to add respecting those which occur in the coal series or elsewhere; while, for the minute descriptions of these, and of those which are found in the tertiary deposits, I must refer to the authors who have described them. But I must proceed to add what applies equally to this and to the preceding chapter, and which I therefore reserved to this place.

The remark is general; I have often made it already.

The groups which I have thus described in conformity to custom, quite as minutely as I think necessary, have been formed under presumptions rather than evidence, and further, being local, have been generalized into models or types for all the earth; while they have also been made deceptive, by adopting a single term for a very compound series, and taking also a single member for that term. If any of the presumed groups is a real one, that must be determined by some definite condition of the earth under which it was formed, not under the hypothesis of a nation or a sect: and, of the true evidence and its value I shall soon enquire, that I may prove, if possible, what geologists have hitherto assumed, and at least separate evidence from hypothesis.

As to the extension of these groups, the red marl is the only one yet proved to be widely spread over the earth: and when one nation infers identities, and another disputes them in favour of its own, philosophical geology turns a deaf ear to both; having shown that the Causes will not thus submit to dictation, and must not be, as they ever have been, forgotten. I have shown that the series in the primary rocks will admit of no such generalizations, of either nature; and, since the secondary have been produced in a similar manner, the same diversity must hold, in both respects. Did I act respecting the primary strata of Scotland as Geologists do about the secondary ones of England, I should maintain them as the patterns for the world: yet they who can now perhaps see the one folly, can as little discern the other, as the Wernerian school was unable to discover the equal fiction of its Universal formations. The hypothesis is the same for both; but that is not yet seen, though it is fully time that it should; since it is not Geology,

though it passes for such. And when Organic fossils are brought forward in proof of identities, it is but to add an utter ignorance or contempt of philosophical zoology and botany to all else; as I have already shown. It will be said that I am here undoing all which Geology has been so long in building up: and this will be said with feelings proportioned to the labour exerted on this limited subject, English topography, and to that affection for an object which is generated by labouring on it. But all hypotheses have made the same complaints: men are irritated at the attacks made on their favourites, and hold fast till they can hold no longer. But it is hypothesis alone that I desire to overset; since, till that is done, we shall not even begin to enter on the right road.

CHAP. XXXVII.

Shale, Clay, Sand, Marl.

The term Shale includes all the secondary and tertiary argillaceous schists; but I do not notice its provincial names, while the ill-judged term slate-clay is rejected, as unnecessary and inconvenient.

It resembles the primary schists so much, in mineral characters, that they cannot be distinguished by any general definition; and though some of its varieties may differ from every one in the latter division, there are many which are undistinguishable. As in other cases, the distinctive character of this rock is compounded of its geological associations and its mineral nature; and it is only through both that it can safely and effectually be recognised. Its varieties are enumerated in the Classification of Rocks; and I need only remark here, that it is more or less indurated, and that its prevailing colours range from grey to black, but comprise also red and yellow hues of considerable variety. When highly ferruginous, it passes into argillaceous ironstone; and, becoming calcareous, into schistose marl, and into limestone.

In this case in particular, or when interstratified with limestone, it is the frequent seat of fossil shells; while the argillaceous beds of such a series often contain a greater proportion of these than the calcareous rock. In the coal series, it often contains bitumen, orcarbonaceous matter, or both; and, in the same circumstances, is the frequent repository of vegetable remains. The most bituminous varieties, known by the name of Kimmeridge coal, are combustible.

Otherwise compounded, it contains mica, or quartz

sand, or both; and, in this latter case, it sometimes passes into flaggy sandstone. It seldom includes distinct fragments of other rocks; but, in Sky, nodules of trap are found in some of the beds. Some varieties of shale, like others of primary argillaceous schist, contain a decomposable pyrites; being, therefore, wrought for alum, under the name of aluminous slate.

When in contact with trap, it sometimes passes into siliceous schist, as elsewhere explained; and, under the same circumstances, often assumes a peculiar concretionary structure, slightly noticed in the chapter on that subject. In the Shiant Isles, in Arran, in Fife, and elsewhere, it thus presents a granular appearance, resembling sometimes a mass of damaged gunpowder, or an agglutinated heap of mustard-seed, at others, of spheroidal concretions like pease. And when the rock is indurated to the hardness of siliceous schist, as is common, the softer intermediate parts wear away by the action of the sea and air, so as to produce a botryoidal surface. In rare cases, as in Fife, such concretions attain the diameter of a foot, resembling those of the sandstones in the same circumstances. The columnar configuration occasionally found in shale, is connected with its transition into ironstone and into jasper; as noticed in the description of this rock.

The range of Geological position occupied by shale, commences with the old red sandstone and reaches to the chalk; and it occurs also in the lacustral and other tertiary deposits. Its proportion to that of the accompanying strata is exceedingly various, while it is commonly interstratified in thin laminæ with them. The tenuity of these is sometimes extreme; and it is rare to find considerable beds, uninterrupted by the

repetition of the sandstones, limestones, or clays which it accompanies. The only exception known to myself, is the sandstone series of Caithness and Orkney; which appears to form two parts of a common deposit. In Orkney, in particular, many extensive tracts of shale occur, covering a great surface, and reaching to so great a depth, uninterrupted by sandstone, that, as far as I can confide in observations on a country so deeply covered with soil and peat, it sometimes attains the thickness of seven or eight hundred feet. Thus it here occupies a conspicuous place among the secondary strata, and may claim the rank of an independent rock.

It is here alone that, in Britain at least, its geographical features can be studied; since here only it is unmixed with other rocks. These features are invariably tame. The few hills are rounded, and unmarked by protruding rocks or abrupt declivities; while North Ronaldsha and Sanda are nearly as flat as the sea which surrounds them; above which also they are so little elevated, that it seems, in winter, to threaten their existence. Yet in Westra, Rowsa, and the Mainland, the abrupt vertical cliffs are more durable than those of the sandstone in the same islands.

The composition and texture of shale, with its ready disintegration, point it out as the parent of fertile and deep soils; though, occurring so rarely alone, there is little opportunity for judging of the fact. In Caithness and Orkney, the covering of peat is commonly so dense and deep, that the soil beneath is as useless as it is inaccessible. Yet where, as in North Ronaldsha, the surface is free of this, the excellence of the soil is indicated by a fertility which, in such a climate, would scarcely be expected.

The œconomical uses of shale are inconsiderable;

yet the most fissile and tenacious varieties serve for roofing-slate and flags; especially when it occurs in the lowest sandstone. It is the repository of metals, like the other strata which it accompanies; but is itself an iron ore, when highly ferruginous; being the ironstone so extensively used in the manufactories of Britain.

Clay, Sand, Marl.

In terminating this account of the secondary strata, I must notice these substances; which, though not rocky, form a portion of the structure of the earth. Sometimes the result of disintegration, they seem at others to be waiting for that induration which occasionally takes place in certain portions without affecting the rest. Thus the clays are found intermixed with shales, the sands with sandstones, and the marls with earthy limestones.

The general position of these among the strata is already understood; and it has been seen that they occur throughout the whole series. In general, they are more important in an œconomical view, than interesting to a geologist; while many of them are undistinguishable by mineralogical characters. The extent of a few, however, renders them objects of greater interest. Such are the clays of the coal-beds, containing ironstone, the marl of Gloucestershire and Lincolnshire, the fen clay, fullers' earth, the extensive formation of plastic clay, and the no less conspicuous blue clay which contains septaria, forming the uppermost material in the London district. Among the sands, the most remarkable are situated high in the series; and these are the ferruginous sand, and the green sand, being portions of the general deposits already described. The others occur among all the several other strata

already noticed, and require no additional remarks here. The reader must be referred, for a fuller account of all these substances, to the topographical and mineralogical works in which they are described. But a few remarks on their present condition will not be useless.

It is evident that the upper clays, such as those of the London district, are now in the same state in which they were deposited; and that, although they might have produced rocks, under other circumstances, they have never existed in that form since their deposition. This seems equally true of many of the inferior strata of the same nature; however difficult it may be to explain why, in certain situations, the same material should have remained uncompacted into stone, while, in others, it has become shale. Yet the remarks in a former chapter have shown that many of these clays have once been in the state of rocks, which have been decomposed within the earth, so as to assume their present form. This, indeed, is proved in Cornwall, where the ordinary argillaceous schist is found converted into clay at great depths, retaining the indications of its former state; as are granite, gneiss, and the traps in innumerable situations. The same remarks may be made on the sands: but it would be merely to repeat the same reasoning; and I need only remind the reader of the proofs of extensive decomposition among these, formerly given. Neither is it necessary to extend this reasoning to the marls; as, in some cases, they are obviously in the state in which they were first formed; while, in others, it is equally apparent that they are the result of decomposition.

But the term Marl has also been applied to a schistose rock, so as to have been the cause of much inconvenience. That of Marl-slate has particular-

ly been a source of confusion; having been considered a primary rock, even when containing the remains of fishes and of terrestrial plants. Schistose marl occurs among the secondary strata, with the shales; and I have every where considered it as a modification of shale, containing calcareous matter, being generally also interposed among strata of limestone. If there be a distinct "marl-slate," it is also a calcareous shale, or a mixture of clay and lime, indurated. It accompanies limestone and sandstone, passing into indurated clay, and into limestone. The well-known Florence marble belongs to this rock. As I had occasion to notice in the account of Organic Remains, it is probable that many of these substances, when more accurately examined, will prove to belong to fresh water formations, and that the error has arisen from not distinguishing between mere juxtaposition and alternation. It is equally probable that many of the Italian examples belong to the elevated alluvia; as those of Monte Bolca assuredly do. Under such palpable errors, I have excluded this substance from its former place among the primary rocks.

The term marl is also applied to recent deposits of shells, either simple or intermixed with clay. These form parts of the lacustral deposits, as already noticed; but they also occur in situations where their origin is much more modern. Thus they are found on shores deserted by the sea, or in the æstuaries of rivers; and thus also they are common in inland situations, and, very often, under peat, as elsewhere described. In this manner they are frequent in Scotland, indicating the former places of lakes long since filled up. Their geological relations are far too simple to require any further detail. But I must yet point out two modes

in which marly deposits are formed independently of the presence of water.

The first of these is from the blowing of calcareous sand, which being deposited on the land, often at considerable distances from its native place, becomes consolidated by pressure and moisture, and at length covered by vegetable soil or peat, or even by terrene alluvia. In this way, inland marl is found in some of the Western Islands, even on declivities. But a more remarkable deposit of this nature occurs in several parts of Perthshire; and, in the *Geological Transactions*, I have described a conspicuous instance in Glen Tilt. These are formed by terrestrial shells; and the depths of the deposits are often very great. For the details, which my plan excludes, I must refer to the original paper, where the animals which conduce to produce them are described.

CHAP. XXXVIII.

General Remarks on the Secondary Strata.

Having thus terminated the account of the secondary strata, it remains to make some remarks on the whole, for which no previous opportunity has presented itself, in addition to the incidental ones already offered. The revolutions which their condition, in some parts, implies, have already come under review; but if I mistake not, there is much remaining, connected with former changes of the earth's surface or condition, respecting which it is exceedingly difficult to reason, for want of sufficient facts. Geologists have neglected to seek for these, because they have not reasoned *a priori*, or respecting causes: taking it for granted that all the parallel strata had been formed, in the simplest manner, under the sea, and never waiting to enquire how an hypothesis so slovenly could be reconciled to the known facts, imperfect as these are. In this broad statement I have hitherto followed them; yet not without occasional remarks, tending to what I must now expand, as far as the wretched scantiness of the matetrials will permit. Be the result as meagre as it may, it forms a portion of the Theory of the Earth, the next in order to that of the Revolutions traced in a former chapter, which, under an infinitely less perfect form in previous hands, had been idly brought forward as A Theory of the Earth.

And the effect of such an examination, should it do no more, will be to show how much we have yet to learn respecting the changes and progress of our globe, and thus at least to point out what is yet demanded from practical geologists. If also it is only among the secondary strata that we can trace these

conditions, we cannot but infer that similar ones must have existed among the primary, since these were once under similar circumstances, though now affording us no clue to those: whence it will be to take a very narrow or superficial view of the theory of even the earlier rocks, to suppose that it is all comprised in those revolutions which I formerly investigated. Yet let me premise this. Whatever inferences may be drawn as to conditions of the surface in this period, I cannot see that we have any right to extend them more widely than visible facts and fair analogies warrant. I have rendered it probable that even the greater revolutions were partial, tedious, and successive, being universal only in their total results; and there is even less right to infer that a theory of English or European strata is to be a theory as to the whole earth, when the very strata themselves are limited.

The needful preliminaries to this enquiry are little more than a restatement of what must already have appeared, if dispersedly, for other purposes. The arenaceous and argillaceous rocks have been generated from the ruin of former ones, and the limestones are the produce of animals. A deep mass of the former, unaccompanied by the latter, marks some condition of the earth, at that place at least, where few animals existed; a similar one of pure limestone bespeaks a reverse condition, attended, in that place, at least, again, by little degradation and deposition; while the mixed alternating strata demonstrate a corresponding mixture of both sources of action. Further, where any stratum contains terrestrial remains, of whatever kind, it follows, that there, at least, it must have been an æstuary, or in some communication with the land, under no deep sea.

And lastly, considering that the degradation of land

can never have ceased, I see no means of accounting for deep limestone masses unmixed with arenaceous and argillaceous strata, except by considering these as the coral banks of a former earth: the present ones being the obvious type of the past, as they are the only limestone formations with which other strata cannot alternate. And that opinion is justified by the predominance of corals in these; while if they also contain shells, this is no more than occurs in the present coral reefs. Correlatively, where limestone beds alternate much with arenaceous and argillaceous strata, my conclusion must be, that these were formed chiefly by colonies or beds of shell fishes; while that opinion also is sufficiently borne out by the nature of the imbedded fossils. The really oolithic strata explain themselves; since their present type is existing in the West Indian islands.

Of the old red sandstone I need here say nothing; having sufficiently shown that it was the produce of tumultuary actions, and of ordinary deposition after degradation, at a time when a new creation of organized beings had but commenced; whence the rarity of those in its beds is explained. The general clue to the explanation of the mountain limestone is already given, in the suggestion respecting coral beds, and in that increase of organic beings which must be presumed to have then taken place; while, when it presents alternating shales, the solution is not less obvious. But respecting the terrestrial fossils which it sometimes contains, I have two suggestions to offer. Either may be true, in particular cases; while there is nothing in the one that should exclude the other.

Adopting the theory of coral reefs, it is easy to account for the preserved vegetables; since in this also, an existing coral island is a type of what might or

must then have been. But we may also adopt the theory of æstuaries; and, in such a case, the deposits of vegetables in the plastic clay, and, as the type of both, the similar ones in the existing alluvia of rivers, as in those of the Ganges and Mississipi, become the explanation. If any one shall prefer this as the exclusive solution of that state of things, he will find arguments in the community of condition, both as to the strata themselves and the imbedded fossils, between the upper beds of this deposit and the lower ones of the coal series. I do not think that our information is such as, in almost any case, to justify our drawing the inferences of geological philosophy too strictly; and I am very sure that the hill of truth will never be reached by shutting up the road which leads to it.

I may pass over the coal series, since this has demanded a separate inquiry; nor need I again notice the revolutions connected with it; so that the next object of inquiry is the magnesian limestone. I think that the characters of this deposit bespeak a very different origin from that of the "mountain" or any other limestone in the series; and can see no solution of its peculiarities but the following, while I must here add the essential facts on which that rests.

It contains conglomerate beds, or fragments, marking its production from the degradation of former rocks, thus far at least, and not, like the other limestones, from the disintegration of animals. Excepting fuci, of which the explanation under this view is easy, it contains no fossil remains, generally at least; and, of those which have been asserted to exist, there are serious doubts; from the inaccuracy of observers, confounding with it some casually associated deposit, perhaps lacustral; while, though they were proved as to certain localities, this may be explained, for those which should prove terrestrial, under the theory of an

æstuary, as may be done respecting similar cases in the old red sandstone, an unquestionable produce of degradation and transportation. And though it should really contain shells in any place, these may be the remains of an organic creation, perhaps yet scanty, whether a renovated one or not, under those circumstances of revolution which depressed the coal strata. It is often oolithic, and further, sandy; facts equally marking its origin in degradation, and consequently, as a limestone, from former limestones; while if its progenitor contained shells and corals, as we know that it did, we might account for even its traces of shells, or entrochi, or whatever else, without the aid of living animals, assisting to form it by their own disintegration.

Considering therefore these circumstances, and conjoining with them the revolution depressing the coal strata, additional proofs of which are found in its conglomerate structure, and in those conglomerates consisting of the mountain limestone, the solution of its origin seems to me this, namely, that it was formed, principally, if not entirely, from the waste of the mountain limestone, remaining partially above the surface after the depression of the coal strata; while some portions have been deposited on this series, and others in a lateral order, under the necessity formerly explained, and while it should not be the produce of living shells, because a living creation should have suffered in the preceding revolution, just as it did in that which preceded the deposition of the old red sandstone.

If this be the explanation, even the magnesia which it contains may be used as an argument, since it occurs also in the mountain limestone; and if it be not received as such, I have but one more suggestion to offer.

That is, that this limestone might, in its upper parts at least, if not in its conglomerates, have been produced by animals, like the others, but that having been exposed to heat during the revolution so nearly connected with it, the fossil bodies had disappeared, as I have shown them to do in the ordinary cases of organic limestones connected with trap. In either case, equally, it might alternate, as it does, with argillaceous and arenaceous strata; but this fact is perhaps more confirmatory of the first explanation. And I also think that the first suggestion is confirmed by the condition of the red marl; an immense deposit from degradation, containing few or no organic bodies, as if a new creation following, or to follow, the last revolution, had either not occurred or not begun to predominate.

The peculiar difficulties attending on this singular sandstone have already been pointed out; and though geologists do not seem to have seen any, from never analyzing nor philosophizing on the facts before them, I must repeat my inability to offer any rational explanation of its sources and nature, beyond that which must be obvious from what I have just said. It should be apparent that it is the produce of the degradation of the supramarine rocks remaining after the depression of the coal, wherever it is actually superior to that series; or existing at the period of that formation, whenever it may be lateral and coincident in time; while the immense accumulations which it presents, together with its wide extent, always under a similar condition, and without intervening beds of limestone, bespeak a long period in the earth, during which an organic creation was scanty, if not absolutely wanting. As far as it may contain organic fossils, whether terrestrial or marine, vegetable or animal, I need not repeat the former suggestions; while they seem appli-

cable to all the strata wherever similar circumstances occur.

Still, it is the presence of salt which offers the great difficulty; and till the cause of this is explained, the history of this deposit must remain one of the greatest blanks in the science of geology; that blank, which, with the philosophy of mineral veins, still utterly unintelligible, and that of the green sand, hitherto unsuspected to be another proof of our ignorance, forms at present the chief very decided deficiency in a Theory of the Earth. If the confession of my own is but that of the general ignorance, this open acknowledgment may perhaps give some force to my opinion, when I say, that in all else, the Theory of the Earth, as it may here be deduced and will hereafter be sketched, wants little to render it as perfect as can now easily be expected, and wants nothing which relates to its essential points.

I do not think it now necessary, in this sketch of the theory of the secondary strata above the coal, to distinguish the muschelkalk and the quadersandstein; since the same general reasonings will apply, though I limit this view to the received English series. All that can be requisite is, to consider these as analogical deposits produced in other places, under the same general circumstances; and thus the same theoretical views will equally suffice for all other analogous deposits, in whatever part of the world they may hereafter be studied. In applying it therefore to the Lias of England, the obvious inference is, that after the deposition of the red marl, an increase of the organic creation became the source of the calcareous beds in this series; while being as yet but few, in comparison to what their power of propagation was hereafter to render them, the argillaceous and arenaceous deposits from the supramarine land bore a larger proportion to

them than in that subsequent condition in which the series of the oolithe was formed. There is no mystery in these calcareous beds, or in this intermixture. The colony of animals, wherever existing, formed the limestone; it was a less rapidly populous one at its commencement than afterwards; and thence are the limestones more scanty below than above, compared to the other associated strata: while, when it was extirpated, from whatever causes, the deposition of the land, always proceeding, formed the intervening strata, separated into sand and clay in the usual manner, until the re-establishment of a new colony enabled a new calcareous bed to be formed. I have already more than sufficiently explained the deposits of terrestrial organic bodies in portions of this series.

A still increasing population produces the superiority of the oolithe series in calcareous strata; while, in other respects, the same reasoning applies as to the intervening ones, under modifications which must be made for each locality, and of which the whole might be explained by adequate attention, from considering the present condition of the earth at different points; its mountains, its seas, and its rivers. And as far as any of its beds are truly oolithic, the modern formation of oolithes under the waters of the sea from recent shells, offers a palpable and simple explanation, while the former ones, as to terrestrial remains, equally apply.

But this simplicity of explanation is about to cease, with the termination, in Europe at least, of this series, so enormous in depth, and thence occupying such an incalculable period of ages in its production. And that production being the result of a long period of tranquillity or of uniformity of constitution and repose, in the earth; since no strata intervene among the limestones of this series, to indicate aught but the *same* consistent degradation of the supramarine rocks

as in the preceding and connected lias; the whole produced in one period of a populous repose, if under a gradually increasing population.

It ceases with the green sand: and here, I fear, geological philosophy is scarcely less at a loss than in the previous case of the red marl; while, in reality, the particular difficulty, surmountable there, seems here to be absolutely insuperable. The degradation of the land goes on, but the deposits of limestone diminish or stop. Sand is deposited, and so is clay; but animals do not breed, or breed scantily, among these deposits. There is no mark of revolution or tumult, the strata are orderly and consistent, and continue to be parallel; yet the organic creation, if it has not disappeared, has been so reduced, that it bears no longer any proportion in quantity to the time required for this deposit. It is not exterminated, because the green sand does contain limestone, marls, and shells; as it also contains lignites and vegetables, the former, in some places, conspicuously.

I can give no solution of this diminution of animals, and through so long a period; I cannot even offer a conjecture respecting what geologists have forgotten to notice, from never bestowing the needful reasonings on the facts before them. Some change in the constitution of the earth, or the water of the earth at least, must have occurred; while, of this, there are no other indications. Must we suppose that something has been overlooked respecting this deposit and the interval which divides it from the oolithe series? This is what geology has still to investigate; and till it has so done, and furnished facts for the explanation of this change, it has left an essential portion of its work unthought of. My own opportunities as to this interval have been few; and when I seek among writers, I find nothing to the *purpose*.

This alone, I may venture to suggest. I have not here noticed the lignite-coal deposits in these strata, because they belonged to a subsequent chapter; but doubting if those in the oolithe could have possessed their present characters without some essential changes in the positions of the surrounding strata, analagous to those in the coal series, as should also be true of those in the green sand, it is probable that there has here been some revolution, to add to all the others formerly noticed, partially destructive of animal life, though not attended with that reversal of positions which marks those formerly discussed. And if this be the explanation, it is probable that some marks of revolution will hereafter be found in this place, by those to whom I have thus pointed out the road which they ought to follow. Should it also prove to be the fact, it will be another revolution to add to those already demonstrated; as, without some such explanation, there must remain a serious blank in the Theory of the Earth.

The theory of the chalk becomes comparatively easy, since it is but to repeat what was already said respecting the calcareous strata following the red marl. Yet with this exception. It is often a deep mass of calcareous rock, without intervening argillaceous and arenaceous strata. Its organic fossils show that it was not a coral reef or island, the degradation of the supramarine land ought to have been proceeding, and yet it is what we see it. I have no solution for this geological anomaly; unless it be this. It is an admittedly partial rock, and considerably limited; and I can therefore suppose that it was formed in seas bounding low lands instead of mountainous ones, from which the deposition of arenaceous and argillaceous materials might be so scanty as to suffer extensive calcareous unmixed deposits to be formed from the spoils

of animals. Nor need the present elevated nature of any lands, now bounding or connected with, the chalk, be used as an objection; since this condition is posterior, being the cause of the elevation of the chalk itself.

I have but this to add. If I have hitherto followed geologists in considering the chalk as the uppermost of the "secondary" and marine strata, as the most recent of those disclosed at the last great revolution of the Earth, it is not that I am satisfied with this received opinion, but that I am not possessed of facts sufficient to controvert it, and to propose a reform of our classifications on this point. Yet is it more than a merely suspicious hypothesis. If there be a stratum, rocky or otherwise, among the marine ones ranked as tertiary, which is parallel to the chalk, it may have been elevated at the same time, and be thus a still higher member of the same series; nor will its partial or limited extent affect that conclusion, since the chalk itself is, like all else, a partial deposit. The case would be parallel to that of the Italian alluvia under other circumstances; and until the "tertiary" strata have been more carefully studied, we cannot be sure that it does not exist. But this is not all. Our gravel beds have, with no small probability, been thought to be derived from a decomposed rock; and if this should be the fact, then is this a stratum above the chalk, to be ranked in the same series, though now an alluvium *in situ*. If the obscure sand of central England is to be considered a marine alluvium when unconsolidated, it is still a rocky stratum in the same series, when consolidated: unless any one can prove that it has been consolidated in recent times. Let us not, at any rate, decide till we are better informed; lest in this case also, we, as usual, substitute hypothesis for fact.

CHAP. XXXIX.

Pitchstone.

THE printed information respecting this rock is so scanty and suspicious, that I dare not borrow from it. As in the case of Trap, some of the remarks on its position have been warped by theoretic views; as the peculiar jaspers occurring under trap, have also been occasionally confounded with it. Under these doubts, I must give its history as far as it can be deduced from my own observations; hereafter, its nature may perhaps be more completely elucidated; but if I have given its true history for Scotland, I must believe that I have done it for the whole world.

The first remarkable circumstance respecting Pitchstone is, its limitation to trap countries, while, even in these, it is rare. In our islands, it is confined to Ireland, and to Arran, Rum, Egg, and Sky. In these situations it forms veins, so decided in their characters, as to permit no doubt respecting their real nature, even where parallel to the including beds; when they resemble the intruding masses of trap which occupy similar positions. They are rarely continued for a long space; more commonly terminating abruptly among the surrounding rocks; while one instance alone of ramification has occurred, in a vein in Egg, divided round a mass of chert. The only mass of pitchstone in Scotland, of which the true nature might be disputed, is that magnificent and picturesque object, the Scuir of Egg. This, however, is a substance intermediate between pitchstone and basalt, and, at the same time, porphyritic. Standing insulated, like a narrow irregular wall, on the surface of a mass of trap, it does not at least resemble a bed; as its mineral character,

no less than its place above a trap posterior to the secondary strata, proves that it does not belong to this series. It is unquestionably the remains of a vein once pervading the trap on which it seems now to stand. The degradation of that rock has left the more durable pitchstone in the position it now occupies; and of this degradation, there is ample evidence. The columnar structure, and its parallelism to the sides of the vein, occur equally also in veins of trap. As there is a striking analogy between pitchstone and basalt, it is conceivable, that, although unstratified, it may at least exist in the form of large overlying masses, like the trap rocks; and probably some of the foreign examples, supposed to be stratified, are of this nature.

If the preceding remarks are not judged sufficient to exclude pitchstone from the stratified rocks, with which it was formerly classed, the following argument may. It is found in granite, in red sandstone, in the more recent sandstones, and in the latest trap rocks; thus occupying a variety of discordant positions which no rock has yet been known to do, excepting the intruding substances of the trap family. In granite or trap, it is obvious that it could not be stratified; nor is there any rock, except Serpentine, which forms veins and regular strata also. Even where it occurs apparently unstratified among the sandstones, it must therefore be considered as a parallel vein.

The entanglement of fragments of the including strata in trap veins, is so common as to have fallen under the observation of every geologist conversant with these rocks. But if in pitchstone, it is so rare that I have as yet observed only one example, it occurs in the well-known vein of Brodick wood in Arran. The including strata consist of the red sandstone; and fragments of it are insulated in the middle of the

vein. If this occurrence is as yet solitary, it must be recollected that it does not happen, perhaps even in one trap vein of a thousand; so that it may be merely a question of chances, depending on the much greater rarity of veins of pitchstone. The fact, even if solitary, is valuable; as establishing, in another important particular, the resemblance between pitchstone and the trap rocks.

There is no stronger proof of the common origin of pitchstone and trap, than the transition from that substance to basalt, which is sufficiently common. The Scuir of Egg holds a place intermediate between the two. Nor are similar transitions rare in basaltic veins; particularly where one traverses another of a larger size. In Sky and elsewhere, the basaltic veins which ramify through the hypersthene rock, become gradually finer in texture as they divide, until the minuter filaments are converted into perfect pitchstone. In the same place, there is a large basaltic vein graduating into pitchstone at its side; and in Lamlash, where a vein of basalt passes through one of greenstone, the outer parts, to the depth of half an inch, are formed of a glossy black pitchstone. In some places, this outer lamina is very decided and distinct; but, in others, it graduates into the basalt of the vein, by an intermediate substance, resembling that of the Scuir of Egg. And in one of the veins in this island, the outer part is a perfect and brittle pitchstone, while the inner is formed of the same intermediate substance. With this identity of geological relations and origin, there is this important difference, that while veins of trap are very persistent, and are always connected with some fundamental body, those of pitchstone are limited in extent, and have not yet been traced to a principal mass.

Veins of pitchstone vary considerably in breadth, ranging from many yards to a few inches; and where basaltic veins become pitchstone during the progress of ramification, they descend to the dimensions of a thread. In composition, they are not always the same throughout; many different qualities sometimes occurring in the same vein. In these cases, the most perfect, or vitreous-like parts, are found at the sides; and they present differences of colour, as well as of texture and aspect. Occasionally, like those of trap, they possess a laminar disposition, parallel to the vein; and, in such instances, there is sometimes a change of substance where each lamina terminates; the pitchstone passing into chalcedony and into chert. In a few cases, they exhibit a prismatic tendency at right angles to their course; while that which forms the Scuir of Egg is divided into columns somewhat parallel to its sides, but so placed with regard to the planes of the vein, and so entangled, that the ends of many of them are extenuated by being compressed between the middle portions of those adjoining.

The internal structure of pitchstone is various. Occasionally, it is uniform, breaking in every direction alike, with a fracture more or less perfectly conchoidal, or flat, or splintery, or imperfectly granular, or compounded of two or more of all those. In other cases, it presents an internal concretionary structure; the concretions being irregularly spheroidal, or prismatic, or cylindrical, or lamellar of different sizes, and either straight or curved. In a few instances, the prismatic concretions are jointed, with surfaces alternately concave and convex; each joint sometimes also containing a central atom of felspar, or of a white enamel. Through the spheroidal structure it passes into Pearlstone, as I shall immediately show; these being here considered as varieties of one rock; though for the

details of these and other modifications I must refer to the Classification.

Pitchstone presents many other remarkable analogies to trap in its structure. It is often porphyritic, containing imbedded crystals or irregular grains, of felspar, and, occasionally, of quartz also. This is an interesting circumstance in its history; as it is found only in the unstratified rocks, with the exception of porphyritic gneiss and schist, or in those which intrude among the truly stratified substances, in the form of veins. The porphyritic structure is indeed so common in the pitchstones of Scotland, that the instances of it far exceed those of the simple rock; particularly in Arran. It is rare to find any mass which does not in some place contain imbedded crystals, or, at least, rounded and irregular grains of felspar.

Admitting, as now demonstrated, the igneous origin of trap, a remarkable circumstance occurs in some of these pitchstones, which, together with its other analogies, equally indicates the igneous origin of this rock. Nothing indeed of this peculiar and demonstrative nature has occurred, even in any of the porphyries which have come under my examination. In the porphyritic examples in question, the grains of felspar are rounded, but irregular; retaining the usual plated structure in the centre, but gradually becoming confused towards the surface, and terminating in a coating of white enamel, such as is produced by the fusion of felspar. This felspar is, in some cases, the glassy variety, in others, the common; and the change on the crystal is precisely that which may be induced by the regulated action of the blowpipe, while the smaller grains consist entirely of the enamel. These singular varieties occur in Sky and Arran; and it is interesting to remark, further, the connexion which they possess with pearlstone.

In tracing the progress of common pitchstone to pearlstone, an obscure spheroidal concretionary structure will first be found, which, by an increasing distinctness of the concretions, causes them to pass into the latter substance. In other cases, the enamel grains are the centres of a spheroidal tendency; and such varieties are imperfect pearlstones. In those of decided character, the grains, or spherules, contain a central enamel; and these have been called pearlstone porphyry. Further, in some instances, the enamel and the investing pitchstone spherule seem to have entered into combination; the result being a pearlstone of a peculiar character, but in which the enamel grains may still, in some part or other, be discovered. Lastly, in some rare instances, as in Arran, the felspar crystals consist of successive concentric prisms: a layer of pitchstone being interposed between each, so as to produce a compound crystal.

The amygdaloidal structure, so common in the trap rocks, is so rare in the pitchstones, that only one instance of it has yet occurred. The specimen was from Baffin's Bay, containing zeolites, (mesotype or nadelstein,) and resembling, in all but its base, the basaltic amygdaloids.

The decomposition of Pitchstone is an interesting part of its history. Though apparently compact, it contains a considerable quantity of water, and is thus frequently very tender and fragile, when not exposed to the air. In wet places, it is easily resolved into clay; a circumstance, among many others, marking its complete distinction from obsidian, with which it has sometimes been confounded. But even when highly tender, it resumes its original firmness after being dried by exposure. Like some of the trap rocks, it occasionally betrays, on the exposed surfaces, marks of a concretionary structure which would not other-

wise be suspected. Thus it desquamates in solid crusts; the only change which these have undergone, being the loss of their colour, causing them to resemble white enamel. This may possibly arise, as in granite, merely from the effects of the atmosphere; but the same exposure sometimes detects a structure which is unquestionably internal, consisting in waving and intricate lines, alternately dark and light; proving that the rock consists of an intermixture of two distinct compounds, and further, that it has been contorted while in a semi-fluid or flexible state. This fact may be added to its other analogies with the trap rocks, in confirmation of the opinion that, like those, it owes its origin to igneous fusion.

The ordinary transitions of pitchstone, besides those into basalt, are into chalcedony, chert, and semiopal. It appears also to pass into a substance not easily distinguishable from the conchoidal shining jasper found among the clay strata that are entangled in trap or in volcanic rocks; with which it appears to have been habitually confounded. It is scarcely necessary to define it further than to say that it is distinguished from all other rocks by its vitreous or resinous aspect; and that it differs from obsidian, with which it possesses in fact no affinity, by its inferior hardness.

At this stage of such a work, it would be almost an insult to a reader to detail the variations of igneous action whence, with a common origin, pitchstone differs from the proper trap rocks. A different original material, a quicker cooling, preventing crystallization, fusion *in situ*, and re-heating, will explain every peculiarity, from the independence of the veins to the formation of pearlstone; and the student will profit more by applying his own reasonings on the chemistry of rocks to these appearances, than if I had occupied some pages in explaining them.

CHAP. XL.

Jasper, Siliceous Schist, Chert.

As these three substances are produced by the casual influence of heat on certain ordinary strata of aqueous origin, occurring also both among the primary and secondary, I have, for the first time, introduced them into the system of rocks, as having been both neglected and misunderstood; while, by thus uniting them, they will best illustrate each other, as well as the philosophy of Geology.

Our information respecting Jasper is very imperfect, as it has not received much attention from geologists, by whom also it has most commonly been misapprehended; though mineralogy is not deficient in descriptions of its varieties. As yet it has not been found occupying large spaces, or forming mountain masses; though carelessly said to occur in this manner in Siberia, where, if it has been thus conceived to possess a considerable extent, the leading mass has probably been some other rock, of which certain portions had assumed its characters. In this manner it does actually occur in Siberia, and in the Apennines, in large masses imbedded among the primary strata; as also in Scotland, between Blairgowrie and Stonehaven, but on a very limited scale. According to Soulavie, it is found, in France, between granite and basalt; a position, which, according to the view here entertained of its origin, is as instructive as it is to be expected. Its peculiar situation in the Apennines, described by Brongniart, was already noticed.

Under these circumstances, I have been unable to derive from the works of authors, except in the above-mentioned instances, any information that could be

relied on; while the name jasper has been applied in so vague a manner as to lead to great confusion. Being a commercial as well as a mineralogical term, it is impossible, without a sight of the specimens in question, to understand always what is intended by it. It is a sufficient example of this laxity, that even the calcareous stalagmites of Sicily have been called by this name; but it will be useful to point out a few of the substances indiscriminately included under it. Siliceous schists, whether from the primary or the secondary strata, have been called black jasper and striped jasper, according to their colours; as have the coloured cherts produced from argillaceous limestones accompanying them. The cherts coloured by chlorite and by the brown oxydes of iron, being modifications of that chalcedony which forms heliotrope and brown carnelian, have also been enumerated among the jaspers; as have veinstones consisting of fragments entangled in coloured chalcedony or agate, together with many other hard stones, which, with an uniform texture, possessed an aspect more or less earthy, and an ornamental appearance, whatever may have been their origin and connexions. Further, it has been applied to the highly indurated clays of a fine texture which are associated with trap without belonging to it, and, more rarely, with granite; as also to real trap claystones when presenting the same peculiar characters; yet being commonly limited to highly coloured varieties.

To these two last substances ought this term to be confined, as they cannot well be expressed by any other, and as all the preceding ones may easily be ranked nnder the several heads to which they belong. Thus the term jasper will become useful in a geological view; without innovation, and merely by limiting it to one of the best characterized of the various *substances* to which it is indiscriminately applied. If

used in this sense, it will be found to occur in different geological situations; being evidently changed, like the siliceous schists, from a different original condition to its present form, through the influence of trap, and sometimes also, of granite.

The most obvious case of this nature, is where it occupies beds, of various extent, lying under masses of trap, or interstratified with it. Here, its true origin is often easily traced; as certain portions of the same beds will often be found to retain their natural and original characters, from having been less exposed to the surrounding influence. The analogy between such jasper and those semi-artificial substances termed porcelain-jasper is very striking; and I need scarcely point out its resemblance in origin to those which occur among volcanic rocks. The transitions of this variety are into the coloured clays which attend the trap rocks, or else into the argillaceous sandstones; while the qualities and the colours vary accordingly: these having formed the original beds, and this result being an important fact in the history of trap also. Thus, a green clay, in Iceland, produces green jasper: in Sky, yellow and red ones, of a resinous lustre, accompany beds of yellow and red clay; and in Salisbury craig, and at Stirling castle, where red and yellow argillaceous sandstones have undergone the same change, the accompanying jaspers correspond to them in colour and in mineral character. In the latter, the resinous lustre is either wanting or obscure; and thus it is easy to account for the various texture and aspect of this multifarious family. Those which have a resinous lustre with a conchoidal fracture and a smooth surface, have been confounded with pitchstones, even by mineralogists of reputation; giving rise to the incorrect notion that pitchstone was a stratified rock;

and it affords an excellent example of the errors which arise in geological reasonings, from an ignorance of the true characters of minerals and rocks. On examining the specimens found in collections, called Hungarian pitchstones, it will be seen that the greater number consist of this jasper. It should be superfluous to remark, that the same substances occur where trap veins pass through strata capable of undergoing the same change.

In the claystones of the trap family, the progress of induration is commonly such as to cause them to pass, through various stages, to compact felspar, as it is commonly called. But, in certain situations, the same claystones are found passing into jasper; being highly indurated, without acquiring the peculiar character of compact felspar. This alteration seems to occur chiefly among the older claystones and porphyries which accompany granite; and there is no difficulty in tracing its progress, even into the porphyries themselves, as the cause must also be obvious. Thus there are formed porphyries with a base of jasper: while, as in every other case of such transitions, specimens of doubtful character become the inevitable consequence. Such jasper also occurs among the secondary claystones when in contact with masses or veins of other traps; and lastly, as irregular masses among the primary rocks, occupying situations analogous to porphyry or claystone, but presenting no transitions into these, by which to indicate an identity of origin. If nevertheless it is probably the same, we are yet in want of information on this part of the subject. It is thus apparent, that jasper belongs, indifferently, both to the primary and secondary divisions; but it would be a needless nicety, in this as in other cases, to form two distinctions.

The forms of jasper necessarily vary according to the original characters of the parent substance. It sometimes occurs in obscure irregular masses, like limestone or serpentine; while, at others, it appears to consist of true strata. The foregoing remarks explain this latter form; while the irregular one must occur when it constitutes an incidental member of the overlying rocks. It is equally obvious how it may occur, either among the primary or secondary rocks, in small portions, of no peculiar form or character: these being regulated by the actual contact or influence of trap or granite at those places. It is also found in the shape of veins, sometimes very minute. In some cases, these seem analogous in their origin to trap veins; as when basalt, in the progress of ramification, becomes pitchstone: in others they appear to have been portions of clay entangled among trap, and indurated instead of being fused.

Jasper presents some modifications of structure requiring notice. Such are the indications of a spheroidal concretionary one similar to that which occurs in siliceous schist; and thus also it sometimes possesses, like these, a schistose structure. The common striped and spotted jaspers proceed from these modifications; and it is thus easy to understand how it may often be difficult to distinguish between the siliceous schists and the jaspers. A minute columnar structure is sometimes also found, resembling that of the argillaceous ironstones, or ferruginous shales. This is readily understood; because these very shales are converted into jasper by the contact of trap, and the limits between the two are often undefinable. This columnar structure is occasionally peculiar, being divided by protuberant joints, and striped parallel to the axes, so as to resemble madreporite limestone.

The large columnar structure formerly mentioned as occurring at Dunbar, is very instructive; because the original beds consist of shale and sandstone, and the different jaspers which result from the induration of both, remain as distinguishable as the original substances.

I know not how to frame a satisfactory definition of jasper; but, in general, it may be conceived as an extremely indurated clay, of which certain varieties approximate to hard pottery, and others to porcelain. Having no predominant texture, it is equally frangible in every direction; and though the fracture is generally minutely granular, and the surface arid, it is occasionally splintery, or even conchoidal; while the minuter fragments may even be translucent. It is not easily confounded with any rocks, except the indurated claystones or the pitchstones. From the intimate nature of their connexion, it cannot always be distinguished from the former. From the latter, it is more easily discriminated, by the absence of the resinous lustre and peculiar transparency of the fragments; although pitchstone sometimes approximates to it in aspect. If Nature has not created definite boundaries, it is in vain for mineralogists to attempt it. For the varieties, I must refer to the Classification of Rocks.

Siliceous Schist.

So thoroughly has this rock been misapprehended by geological writers, that I must, as usual, limit these remarks on it to my own observations. That "flinty slate," as it is called, can have no claim to be a leading rock in the system, as has been stated, will be immediately seen. It occupies two distinct situations; the one among the primary, and the other among the secondary strata; appearing, in both, to be an acci-

dental or local variation of those schists with which it is associated, and owing that change to the influence of other neighbouring masses of rock. It is equally unnecessary, here, as in the case of jasper, to form two divisions; although the characters of this substance differ in the two classes.

When siliceous schist occurs among the primary strata, it forms a portion of the beds of argillaceous schist with which it is connected; and as these vary in their general characters, it presents corresponding differences. It does not appear ever to form extensive masses, as has been asserted, or to be an independent rock, like argillaceous schist. This error has arisen from deducing the nature of such a mass from the examination of a casual specimen; or from investigating those few beds only of a body of schist, which happened, from their situation, to put on this character. If the position of that portion of any mass of primary argillaceous schist which exhibits the character of siliceous schist, be examined, it will be found to lie in the immediate vicinity of granite or porphyry, whether in masses or veins, or of the more recent trap rocks. If, in any case, such causes are not apparent, we know that these intruding rocks often lie immediately beneath the surface, though invisible, and have often been removed, by posterior waste, from the places which they once occupied. Numberless facts occurring in granitic districts prove that this is the true theory of siliceous schist; while it is confirmed by the analogy of those found among the secondary strata, produced only when masses of trap come into contact with the soft shales. And, that the cause consists in the action of heat, is justified by chemical experiment, as well as by the peculiarity of their position with respect to the igneous rocks, and by the gradation

through which they pass into the ordinary schists of which they form a part. The connexions of this kind of siliceous schist being regulated by those of the original substance, require no further notice. But, in similar circumstances, the finer varieties of micaceous schist become also occasionally indurated; and as some geologists have given to these the name of siliceous schist, it must be recollected that such varieties will be found in the same associations as the unaltered rock from which they have been derived.

As I have, on every occasion, preferred the fountain head of all authority to the quoting of authors, I shall here refer to some examples in Scotland, in confirmation of these views. They may be seen in Arran, on the skirts of Cruachan, and in Kirkcudbright and Aberdeenshires. But the promontory of Busta in Shetland presents the most perfect illustration which can be desired. In this spot, a body of slate is traversed by granite veins originating in a neighbouring mass; and the progress of the change, with the relation which that bears to the proximity of the granite, is every where distinctly visible. In many places, this has insinuated itself in a direction parallel to the laminæ of the schist, so that detached specimens appear to consist of alternate layers of each rock; while there is also a gradation from the common argillaceous schist, through the siliceous, to a hornblende schist, as formerly noticed under that head.

The siliceous schists which occur among the secondary rocks, present somewhat greater varieties of character; with certain essential differences, bespeaking their origin even more forcibly than their connexions in the case of the primary. They accompany beds of shale which may alternate with limestone or sandstone, and can easily be traced into them through a

regular gradation of hardness. They never occur except where such strata are in contact with masses or veins of trap; displaying the most perfect characters in their immediate neighbourhood, or where a fragment of the strata is entangled in a mass of trap. Where the original shales alternate with limestones and sandstones, corresponding alterations occur in those substances also. The pure limestones become crystalline, while the argillaceous are converted into a species of chert. The calcareous sandstones are also converted into other varieties of chert, as the purer become indurated, or, if much charged with clay, are changed into an imperfect species of jasper; while the finer clays are sometimes also converted into jasper, as already noticed. If the original shale has contained shells, these are also occasionally found in the siliceous schists; though often deformed by pressure, or otherwise rendered comparatively obscure. When the shale has contained bitumen, carbon is also found to be a constituent of the siliceous schist.

In general, the original form of the beds is preserved, even where the change is so complete that the substance cannot be distinguished from basalt; but, in other instances, the loss of form is complete. Hence, irregular and unstratified masses of trap result from the changes which the shales, or perhaps even the primary schists, have undergone; and this has probably occurred in many cases where we are unable to trace it. The proof is found, as formerly noticed, in masses of trap, or of porphyry, containing imbedded fragments of schist, where the progress of the change can also be traced in these fragments: the schistose structure remaining perfect in one part, while, in another, it vanishes gradually into the irregular surrounding mass. And as the primary siliceous schists pass into hornblende schist, *so do the* secondary ones into basalt

of which hornblende is a constituent part; the analogy of the respective causes being apparent, and serving to add to the proofs already given, that the influence of granite and porphyry in the one instance, has given rise to those changes of character which, in the other, have been produced by that of trap.

Examples of siliceous schist in the situations now described, are well known in the trap districts of Ireland. In Scotland they are frequent; but the most satisfactory examples occur in the Shiant isles and in Sky. In the district of Trotternish (Geol. West. Islands), the gradual change from shale to Lydian stone, the distance to which the influence of the trap reaches, the corresponding effects on the pure and on the impure limestones and on the clays, are such as to afford a demonstration of the causes, as perfect as if the same substances had been exposed to the action of ordinary heat. It is unnecessary to repeat the arguments which these facts add to the igneous theory of trap: nor how the occurrence of the same appearances in the same kinds of rock when near granite, tend to confirm the igneous origin of that rock also.

It is plain that no general definition can comprise substances so variable as those which are ranked under this head. Even if divided into the two classes of primary and secondary, the difficulty is not removed. Though the prevailing varieties were described, the knowledge of the rock in nature must still be derived from the examination of its geological connexions, from a comparison with all other rocks with which it might be confounded, and, perhaps, from a certain degree of that traditional information, conveyed by authenticated specimens, without which the knowledge of rocks and minerals will always be of difficult acquisition.

I may however, remark, that the primary siliceous

schists commonly present the general aspect of the argillaceous ones, and possess a much greater degree of induration, which, at the same time, does not arise from the predominance of quartz. It is necessary to avoid confounding them with the hard argillaceous schists which derive that property from this mineral, and which have often been mistaken for real siliceous schist by geologists of reputation. It is now almost superfluous to observe that they often contain hornblende and thus pass into hornblende schist. Those of the secondary class are far more distinguished from the shales which they accompany, and approximate more nearly to the igneous rocks to which they owe their origin. But, even in these, the schistose, or the stratified disposition, can generally be discovered in nature, though it may not be apparent in a hand specimen. If other substances alternate with them, if they present laminæ of different colours, or contain organic remains, they are easily distinguished from the trap rocks, even when detached from their connexions. It is scarcely possible to confound them with any other rocks; from the whole of which they are distinguished by their great brittleness, the cleanness and sharpness of their fracture, and the absolute uniformity of their texture; the surfaces being frequently as fine and smooth as those of common flint. That they sometimes contain the organic remains of the original shales, though much obscured, was already noticed; and thus have incautious observers described shells as found in basalt.

Chert.

If the very limited extent of this rock may seem, to the superficial observer, to render it insignificant, the peculiar circumstances under which it occurs give it a

high interest in the estimation of the philosophical geologist. If now first introduced into the system of rocks, it could not have been omitted from an arrangement including jasper and siliceous schist; to which it is intimately allied, by its transitions, and by its geological situation and origin. The reasons for adopting this form were given in the Classification of Rocks.

As in the case of the siliceous schists, no general definition of these cherts can be given. They often resemble very accurately the mineral of that name which is so nearly allied to chalcedony and flint. In others, they may be compared to certain species of pottery, with which they correspond in the cleanness and sharpness of their fracture, in the uniformity of their texture, and in their hardness; thus also, often resembling porcelain jasper. They are most commonly simple; but, occasionally contain imbedded grains of quartz or felspar. Originating in limestone, the transition from that rock into the chert, is often so gradual, that no precise point can be assigned where the term indurated limestone is no longer applicable. It is repeating a preceding remark to observe, that where trap occurs in contact with a complex series of limestone, it will, in the same place, induce the crystallization of the pure beds, and change the argillaceous ones into chert; a now superfluous proof of the source of this substance.

Chert, like jasper and siliceous schist, occurs both in the primary and secondary classes; and for the same obvious reasons, since the earthy limestones in which it originates, are found in both. In the primary rocks, granite, or porphyry, as well as recent trap, may produce that effect which, in the secondary class, can proceed from trap alone. To describe the geological situations of this rock, would be therefore to repeat

much of what has already been said; as it is found in the same situations, and very frequently in company with siliceous schist. This remark is however chiefly applicable to the secondary division of that rock; and the reason of this will be found in the generally superior purity of the primary limestones; whence the only change they can experience from granite or porphyry, is that of crystallization. As however the primary limestones are occasionally intermingled with siliceous and argillaceous matter, either in a state of minute mixture, or in that of a laminar alternation, chert is sometimes found even among these. An attempt to the production of this rock is also often observed where the process is still incomplete; and it is evinced by the extreme hardness which such limestones exhibit in the vicinity of granite; but no decided instances of an extensive and perfect transition from these into chert, has yet occurred within my experience. From the peculiar manner in which granite comes into contact with the stratified rocks, distinct beds of this substance cannot be expected in its vicinity. The change to chert in the approximate limestones, is therefore irregular, and limited to short distances from the planes of contact. This is visible in various parts of Glen Tilt, in Shetland, and in other places. It is easy to conceive that beds of this rock might be formed by the contact of overlying masses of porphyry; but I cannot quote any facts to the purpose.

In the secondary class, the origin of chert is more easily traced, and the quantity is, at the same time, much greater. This arises, partly from the more argillaceous nature of the limestones in this division, and partly from the mode in which the trap rocks intrude among the strata, in parallel veins. In what respect the heat may have been differently modified

in this case, we have no means of judging. The chert of the secondary limestones may as readily be traced into these as the siliceous schists may into the shales: and they vary in aspect and character, as the limestones from which they are derived have contained a greater or less proportion of foreign ingredients. In many cases, the same limited specimen presents an alternation of the siliceous schist and the chert together; the adhesion being produced by the causes to which both the substances owe their induration. I know not that organic remains have ever been found in these cherts, although they exist in the associated shales. From the phenomena, indeed, occurring in all cases where beds of limestone lose their form and original character, through their vicinity to igneous rocks, those remains appear always to vanish in these instances; or, at least, their forms are so changed as to be no longer recognisable; all the materials of the rock having probably entered into one new combination. Secondary chert necessarily occurs in beds, as the limestone whence it is derived does. Within my experience, these are not very thick; nor is that to be expected; since the influence of heat cannot be supposed capable of extending deeply through a bad conducting medium; and since, in the accompanying siliceous schist, the change is often limited to a certain portion of the bed in contact with the trap.

A species of chert is sometimes also produced, as I have already noticed, by the same influence exerted on calcareous sandstones. The character of these is rarely so perfect; and, not unfrequently, they can only be considered as varieties which have acquired an unusual degree of induration. Like the former, they occur near veins of trap; but the changes, as might be expected, are limited to a short distance

from the point of junction. In these latter examples also, it is frequently impossible to determine whether the rock ought to be referred to jasper or chert; a condition of things easily understood by recollecting the very variable composition of the later secondary limestones, and the overwhelming proportions of argillaceous and siliceous earth which they often contain. If it is superfluous to note the support which this rock also affords to the igneous theory of trap and granite, it is interesting to remark that the very same substance is found in the vicinity of volcanic rocks, under similar circumstances; as are siliceous schists and jaspers, wherever the requisite original rocks have been present. These have been a great source of trouble to geologists and collectors, by whom they have been ranked with lavas; a term too often adopted to save the trouble of investigation. That confusion, I have, I trust, now removed, among many more.

CHAP. XLI.

Gypsum, Rock Salt.

Although Gypsum has been ranked among the rocks, it ought rather, like Salt, to be considered an occasional mineral occurring among the strata; but, presenting geological features of interest, it demands consideration here, though, for its characters, I may refer to systems of mineralogy. It occurs both among the primary and secondary rocks; but, while common in the latter, its existence in the former is so rare as to have been doubted by some geologists.

It is, however, described by Daubuisson, as forming thin strata, alternating with micaceous schist, and with primary limestone, near Aosta; and by Freiesleben and others, in other parts of the Alps. It has also been found imbedded in graywacke slate by Von Buch and Brongniart, in the Pyrenees, in Switzerland, and in other places; forming the *transition* gypsum of geologists. Under both associations, the strata are of small extent; or the masses are so separated and mixed with clay, or with the surrounding rocks, that they cannot be considered as forming a stratum.

In the secondary class, it is far more abundant, either in the form of persistent strata or of imbedded masses; but is chiefly, if not exclusively, associated with the red marl. Thus it is found in various parts of Germany, France, England, Russia, and Spain; appearing, in all these, as in other instances, to be peculiarly characteristic, like rock salt, of that particular deposit. They who have described two distinct *formations*, the one superior, and the other inferior to that rock, have probably generalized from local facts.

The last geological situation in which gypsum

occurs, is in that tertiary series found about Paris, and elsewhere; alternating, there, with argillaceous and calcareous marl, while lying immediately above the limestone, and forming distinct hillocks. There are three strata, separated by the same intervening materials; the lowermost containing no extraneous fossils, while the middle one is remarkable for the remains of fishes. The uppermost, sometimes exceeding eighty feet in thickness, and lying immediately below the soil, is still more interesting, as including the bones of various land animals, formerly noticed, and amply described by Cuvier.

Rock Salt.

Although Salt cannot, more than Gypsum, be classed among the rocks, it forms a necessary part of the present enquiries.

It is very widely distributed throughout the earth, as has appeared in the account of the red marl; and its existence may often be surmised from the presence of salt springs, lakes, and saline efflorescences, in countries where its masses are not visible. It abounds in England, having been long wrought in Cheshire; while the salt springs of Northumberland, Durham, and Leicestershire, indicate its probable existence in places which the operations of the miner have not yet reached. In Spain, an extensive repository of it occurs between Caparoso and the Ebro; as does a bed of five feet in thickness, accompanied by gypsum and limestone, at Valtierra. At Cardona, it is extensively wrought, and is also found in La Mancha, near Burgos, and in other places which I need not enumerate. Rock salt, or salt springs which appear to arise from repositories of it, occur in many parts of France; as at Salies, to the south of Thoulouse, at

Saline and Montmorat in the division of the Jura, and near St. Maurice, not far from the regions of perpetual snow.

The salt deposits of Germany are noted for their extent; commencing at Halle, and passing through Reichentall in Bavaria, to Hallein, Halstadt, Ischel, and Ebensel in Austria, till they terminate at Ausse in Styria. The same formations occur in Transylvania, upper Hungary, Moldavia, and Poland; ranging along the chain of the Carpathian mountains for more than five hundred miles, from Wieliczka to Rymnick. Those of Wieliczka and of Bothnia are celebrated, from the highly-coloured descriptions of travellers; but those who are desirous of real information, will consult the more sober details of Townson.

Salt springs abound in Russia: and, in the Crimea, in the government of Astracan, and in other places, there occur salt lakes which are supposed to owe their origin to unknown repositories of that mineral. The country which surrounds the Caspian Sea, is every where impregnated with salt; and, in Siberia, it is found at Kolwan, Irkutski, and other places. It appears also to abound in Tartarian China, on the table land of Great Tartary, in Thibet, in Hindustan, and in Persia. Ormus contains it in great abundance; and, in the desert of Caramania, it is sufficiently common and solid to be used in building.

Limited as is our acquaintance with Africa, the sands of the northern districts are known to be impregnated with it, so that the wells are often useless; while here, as in many parts of Asia, the sand is often red and accompanied by gypsum; indicating that its connexions are the same as in all other parts of the world. To the southward of Abyssinia, it is found in solid masses; as it is on the mountains westward of

Cairo, extending, according to Horneman, for many miles. The salt rocks of Tegara, near Cape Blanc, are noted; as are those of Had Delfa in the district of Tunis, of Bamba, and of Congo; forming one of the most important articles of interior commerce in these countries. As in Caramania, Herodotus informs us that rock salt was antiently used in the desert of Libya for the purposes of building.

It was already noticed that salt is found in Peru ten thousand feet above the level of the sea; and, on the western side of the Missouri, it occurs in different places, along a ridge of mountains extending for eighty miles. Salt springs abound in Kentucky; and the saline soils of northern America have long been celebrated for the resort of wild animals, and for the antient skeletons buried in their vicinity. I need scarcely say that the geography thus detailed is nearly a repetition of that of the red marl.

The disposition of rock salt is not rigidly the same every where, nor does it ever seem to form such continuous strata as those of the accompanying rocks. At Thorda, it is said to be found in horizontal and undulated beds. In Spain and elsewhere, though asserted to form continuous beds, and even mountains, more accurate examination has shown that these consist chiefly of the clay and sandstone which constitute its repositories. The supposed strata of salt are thus, rather, strata of earthy matters, among which it is disposed in irregular portions of beds, and in shapeless masses of all dimensions, surrounded by the rocks and earthy substances with which it is associated.

The disposition of the salt of Cheshire is remarkable. Though the general mass appears continuous and compact, it is divided into irregular columnar shapes, or into rounded bodies which appear mutually

to have compressed each other into polyedral figures. That these are formed of concentric coats, is proved by their sections; which display analogous lines of colour, arising from the varying purity of the mineral in the different layers, disposed in the same manner as in the columnar sandstone formerly described.

The position of rock salt in the general series, has not, in every instance, been ascertained. Yet, in most parts of the world, it has either been found decidedly associated with the red marl, as already indicated, or appearing to have been once united to this widely extended deposit. In Cheshire, the evidence is unquestionable, as it is in many other parts of Europe; and as, in Asia and Africa, it occurs with red sand, and is often accompanied by masses of gypsum, it probably belongs to the same series, now decomposed, and often dispersed or obscured. It must, however, be added, that, in some parts of Europe and America, it passes the bounds of the red marl on both sides; so as sometimes to occur in the limestone beneath it, and at others in that above. In some such cases, where the limestones alone have been visible, it has been described as belonging to them. It may, indeed, exist in these without occurring also in the sandstone, or be found where that is not present: but this will not materially affect its geological history, when we consider that it was the produce of partial actions, during the general period of a deposit which must, in the upper and lower parts, have been of nearly the same dates as the calcareous rocks in contact with these.

The frequent occurrence of gypsum with salt, is thus explained; as this mineral is equally associated with the red marl, and as the beds of clay with which it is intermixed are those which, in many places, form so

large a part of the same series. The section given by Townson of the mine of Wieliczka, is obviously no other; consisting of a succession of clay, sand, marl, and sandstone, reaching to a depth of two hundred and forty feet.

It is not surprising that the origin of rock salt has been a subject of much enquiry among geologists: yet nothing like a rational theory has yet been offered. It is far easier to show that the most simple and obvious hypothesis is wrong or imperfect, than to propose a probable one. The origin of gypsum is not less mysterious, even with every conjecture we can make respecting the presence and acidification of sulphur: yet this enquiry has never excited the same anxiety. No rational explanation has yet been suggested; and I have none to offer. But we must seek for the greater ambition of geologists on the subject of Salt, in their wish to derive these deposits from the waters of the ocean in a simple and direct manner; seizing on one obvious analogy only, to the neglect of other possible modes of explanation. That it has been the produce of the ocean, is possible; since the rocks among which it is found are indebted for their existence to the same source. Yet no obvious method of accounting for its peculiar appearances or limitation, can be engrafted on that general admission; while it were as well for geology, and in other matters than this, if they who deposit pure rock salt in the Mediterranean, at this day, would learn at least as much of Chemistry as the "Chemist" of three blue bottles. The desiccation of saline lakes will not account for it, because subterranean salt is far more pure than that which must be the produce of the evaporation of the sea. The mode in which it is disposed will not admit of this explanation; and still less can any system of

evaporation account for the concretionary structure of the salt of Cheshire.

To these difficulties it must be added, that the depth of sea water required to produce, in this manner, some of the larger masses known in Europe, is incomprehensible. It might also be asked, why marine organic bodies have never been found in or near it, and wherefore it is accompanied by gypsum. As it is, lastly, true, that the strata which lie above it have been deposited under the ocean, it is impossible to comprehend how, under these circumstances, evaporation could have taken place. The subject is beset with difficulties; fortunately for the cultivators of a science, which would lose the greater part of its attractions were there nothing left to explain. As to the theory which derives it from volcanic actions, it seems useless to discuss such a question, when no volcanic rocks accompany these deposits in the sandstone, and when, with some very slender exceptions, deposits of salt are not found attending on this class of rocks. Were this the cause, it would remain also to be explained why it is limited to the red marl.

CHAP. XLII.

Coal.

As there are few subjects in the range of geology more important than the natural history of coal, so there is none which has experienced a greater share of attention. There is no want of materials therefore towards a history of this substance, as it occurs in Britain at least; since these have been displayed with all the minuteness which attends subjects of great practical interest. If geologists have not equally done their duty, the cause must be explained by those who have had opportunities without profiting by them, where it has not consisted in the theories which have so long oppressed this science. But though a correct notion may possibly be formed of the geological relations of coal in the British dominions, the information which we possess relating to its disposition in other parts of the world, is far too meagre to permit a confident view of its entire connexions.

The coal of the more recent secondary, of the tertiary strata, and of the alluvial soils, is described in the following chapter, under the term Lignite, in conformity to the division of Brongniart rather than to my own judgment; as some of that found under basalt, is also included under the same head, and as the remainder, improperly erected into a division by the name of basaltic coal, will come under review as part of the history of the ordinary deposits. It does not form a distinct geological variety; since the phenomena by which it is characterized are those of all the secondary strata which are influenced by trap rocks. Thus this chapter is allotted to the history of that coal which occurs immediately after the moun-

tain limestone, and which has been, with an improper exclusion, termed the Independent coal. But as no opportunity has yet offered, for considering that which occurs among the primary strata, I must here give it a place; that, in this and the following chapters, the whole question relating to this mineral may be seen in one continuous view.

The connexions of primary coal present very little interest or instruction, beyond the mere existence of this substance among primary rocks. It has occurred in gneiss, in micaceous schist, in primary limestone, and in a conglomerate rock said to belong to the primary class. Thus it has been discovered in various parts of the continent of Europe, as in France, Norway, and Germany; but as yet no example has been observed in the British dominions. In all these cases it forms very limited masses; being, in some instances, in detached lumps; in others, in forms said to resemble those of veins rather than strata. I need not say that a thin and non-persistent stratum is easily called a vein.

The origin of this coal remains a matter of dispute among geologists. When the mineral carbonaceous substances occur among the secondary strata, they commonly carry their proofs of a vegetable origin with them, as will be shown hereafter. If it may not be so easy to admit this in the case of primary coal, it does not imply any impossibility. I have shown, in former chapters, that organic animal remains do exist among the primary strata; and as I need not repeat the reasonings then given, this hint will suffice for the possible explanation of the origin of primary coal. That it should occur in limestone and in a conglomerate, are analogies to its position in the secondary rocks, of which the value is here obvious.

Admitting even the hypothetical supposition of the absence of dry land in those remote conditions of the globe which produced the more antient marine animals, the existence of marine vegetables would explain the formation of carbonaceous matter; as these are known to be now forming deposits of peat. That these vegetables actually occur, and even in the older schists, is now well known.

Primary coal thus offers an analogy to the lignites of the upper secondary strata, rather than to the proper coal series; nor, if I have succeeded in showing that vegetables might have existed in some antient states of the globe, is there any difficulty in accounting for its occurrence. Organic animal remains might have been utterly destroyed by the revolutions which they have undergone; but the indestructible nature of charcoal, when protected from air, explains, without difficulty, how vegetable ones should have been preserved, so as to have produced the coal of the primary rocks.

But as long as the true nature of elementary carbon remains unknown, this question must also remain obscure, or subject, at least, to dispute. If the diamond be a mineral production from elementary carbon, primary coal may have the same origin. The existence of plumbago offers a parallel difficulty; occurring, as is well known, like coal, among the primary strata, in gneiss and in argillaceous schist. If it be of mineral origin, primary coal, or anthracite, differing but slightly from it in its essential nature, may have been derived from the same sources. Yet the coal of secondary origin, containing vegetable remains, is converted into plumbago by the influence of trap; as wood has been in my experiments, and as coal is, daily, in the iron-furnaces; so that even the

plumbago of the primary strata, no less than the anthracite, might as well have originated in vegetables, as that each of them should owe an independent origin to elementary mineral carbon. But I need not attempt to illustrate further a difficulty of this nature.

Yet I must here notice a fact of recent occurrence, and which may prove of great importance in the general history of all coal, as well as of the merely primary, should it have been truly stated. This is the existence of extensive beds of anthracite in Pennsylvania, found in what is said to be quartz rock by those who have examined the ground. If there is no error in this report, it will prove the views here held out; from the analogy of quartz rock and the secondary sandstones; while it will thus also indicate another resemblance between those, and further tend to establish an extensive vegetable creation occupying some parts of the antient globe; connecting, at the same time, the more doubtful coal of gneiss and the old rocks, with that of the secondary strata.

I must yet notice here, some deposits of coal, of more recent origin than the primary, but which do not belong to the proper coal series. They are occasionally found in the old red sandstone in Britain; while a doubt may rest on some parallel observations on the continent of Europe, from the confusion often made between that stratum and the red marl. This coal is partially wrought in some parts of Scotland; and in Arran, it has a character approaching to that of anthracite coal. Thus also coal has been found in the mountain limestone, but in insignificant quantity. Both of these admit of the same remarks as primary coal; but they perhaps serve to confirm the origin assigned to that, by establishing a perfect gradation of this substance through all the strata; while the

presence of organic remains in these rocks, indicates the analogous origin of the carbonaceous matter.

The coal series which has been called *independent*, and the chief object of this chapter, forms the great repository of that mineral in Britain, though not the exclusive one; and its leading character is to occupy a geological position superior to the old red sandstone, and inferior to the new one, or to the red marl. Though I may have failed in truly classing under this head some of the foreign instances here quoted, partly from want of accurate descriptions, and partly from unwillingness to doubt, without sufficient reasons for doubting, this is the noted deposit to which the general remarks formerly made on revolutions of the globe, apply. From those general reasonings are therefore excluded all coal beds which follow the red marl; though I have not attempted to do that in specific instances in this chapter. The term *independent* is misplaced; since it may be equally used, as it has actually been, for the superior combustible deposits, equally independent, under very different geological positions.

As the beds of coal are found accompanying and alternating with stratified rocks, so they are also disposed in strata parallel to them. These strata are in every respect analogous, in their forms, dispositions, and accidents, to those of the rocks with which they occur. In position, they are horizontal, or inclined at various angles, often highly elevated, as is the whole series; circumstances which often lead to their discovery, or facilitate their working; but which also frequently carry them out of the reach of mining operations. To name instances of these various positions, would be superfluous; and if practical miners have dwelt with undue stress on these and the other accidents to which they are subject, it must be attri-

buted to the nature of their peculiar pursuit, and to their limited geological knowledge, or their ignorance of the disposition of the other stratified substances in nature. The philosophical geologist views, in them, examples only, of general laws which have influenced the forms and dispositions of all the strata of the earth.

As the coal strata may be simply inclined, so they are frequently curved: a common fact in all rocks, but often of great value in a practical view, as restoring to the surface those beds which, had they been prolonged in the planes of their first inclination, would have plunged beneath the reach of the miner's operations. Such curved deposits sometimes produce single basins, under the same analogy; the central parts forming a general concavity, and the edges appearing in various places around the circumference.

Similarly, they present continuous undulations, more or less marked, accompanying, as might be expected, the general undulations of the associated rocks. From this cause, or from mere disturbance, they are sometimes found disposed in convergent or divergent strata; offering circumstances of great practical moment wherever they occur. Of similar importance are the ordinary fractures, to which the beds, in common with the rest of the strata, are liable. As is usual among other strata, such fractures are attended by shifts; these being either simple, or accompanied by veins of other materials. In practice, they produce the sudden elevation or depression of the stratum in which the work is carried on; the consequences, in either case, being generally a source of much labour and expense.

The thickness of a coal stratum varies, even from less than an inch, to ten or twelve feet; but it rarely

exceeds two or three, and is, more often, much less. It is frequently also variable in the same bed; and thus particular strata become extenuated till they disappear. Sometimes these beds have a schistose structure; in other cases they are massive; and, in both, they are often divided, like the argillaceous schists, by joints more or less parallel, at angles to the planes of their stratification. Where beds of coal have assumed a more regular prismatic or columnar structure, this has occurred only in the vicinity of trap, as I shall soon notice. But in Glamorganshire, where this rock is not found, specimens occur, of a singular concretionary structure, presenting fibrous projecting ridges disposed in a manner precisely resembling the madreporite called brainstone.

If single beds of coal sometimes occur in one place, they are more frequently repeated in alternation with the rocky strata by which they are enclosed. Such repetitions have been known to amount to thirty and upwards, as in Derbyshire and Northumberland; but they are seldom so numerous. Alternations extending from three or four to twelve, are more frequent; and, in these collections of strata, the beds are, not only unequal in thickness, but very different in quality; so that, either from this or their insignificant quantity, it rarely happens that more than two or three, even in a considerable series, are worth working.

It must have been already understood, from former observations, that the coal series is not every where found among the secondary strata, however steady its place may be where it exists, but that it occurs in distinct tracts often widely separated from each other. These are known, technically, by the term coal fields, and they vary in their characters in different places; not only in their extent and in their depth, but in the

order of succession of the integrant rocky strata, in the numbers and relative proportions of these, and in the numbers, thickness, succession, and qualities, of the beds of coal, They must therefore be considered as independent deposits, varying, as other local collections of strata are known to do, and from analogous causes: namely from having been deposited originally, by independent actions, in separate cavities.

The strata which accompany the beds of coal, contributing to form what is here called the series, consist of sandstones, shales, limestones, and clays. The sandstones are the most abundant, and the limestones occur chiefly or solely in the inferior parts of the deposit; where a species of transition seems also often to take place between the proper coal series and the mountain limestone beneath it. The characters of the sandstone vary; being, in some places, a conglomerate, but more frequently fine; when it is sometimes compact, pure, and white, at others micaceous, or argillaceous, or ferruginous, and tender; occasionally also containing pyrites, and often blackened by carbonaceous matter, or else including distinct fragments of charcoal. Hence it also presents various colours. The beds themselves are either massive and thick, or divided into thinner laminæ by intermediate clay or shale, so as to descend even to the tenuity of roofing-slate. At the lower part of the general series, this sandstone is often a conglomerate, intermixed with shales, to which the name of millstone grit has been given in England; and, in this, limestones also occur. These resemble the inferior, or mountain limestone, though commonly more bituminous, and of a blacker colour.

The shales vary much in aspect and hardness, passing at length into clays equally various, and sometimes

containing bitumen, carbonaceous matter, and vegetable fragments. In the clays, imbedded nodules, or distinct strata of argillaceous ironstone often occur, and in conspicuous quantities; forming the principal supply of ore for the iron-foundries. Galena and blende are sometimes found with the ironstone, as is pyrites in the coal itself, as well as in the accompanying strata; being the not infrequent cause of spontaneous combustion. When porcelain jasper exists, it must be considered as a casual and artificial mineral, produced by this cause. The most singular, as the rarest mineral, observed in this series, is that inflammable substance callèd Hatchetine, imbedded in very small quantities in the ironstones.

Though the coal series is situated between the older and newer red sandstones, it is impossible to give an universal description of its geological connexions. The exact relations, distribution, and number of the strata, throughout even Europe, are far from being satisfactorily ascertained; and as to the world at large, our ignorance is still greater. The difficulty has been much increased by confounding the upper deposits of coal, here ranked as lignites, with those of the present series; the mineral alone, as is too common with geologists, having formed the chief object of attention, to the exclusion of the geological characters and positions. I must therefore limit this description to Britain, where the subject has alone been accurately studied; and thus, supposing the series complete, the old red sandstone and the mountain limestone are followed by the coal series, to which succeeds the magnesian limestone and the red marl, and, subsequently, such other strata as may be present in that particular tract.

Now it is essential to remark, that the old red sand-

stone, the mountain limestone, and the coal series, are all disturbed; being elevated, undulated, and fractured, in various ways, as I have often already been compelled to notice. And it must similarly be recollected, that a new order commences with the magnesian limestone and the red marl; or that they are placed on the coal series and the inferior strata, in an unconformable position, while the lower substance also presents that conglomerate structure which, every where throughout nature, accompanies a new order in rocks.

Hence the first three deposits have often been united, as forming one class, and as if they had undergone but one disturbance, common to the whole. But from the former remarks on this subject (Chapter xxi.), it is plain that the coal series is really distinct, in time and production, from the inferior strata; and hence cannot be always truly conformable to them, though the last general disturbance is common to the whole. If geologists have not, practically, always discovered the complicated relation between the coal series and these inferior strata, it is because this previous view of that necessity has not been taken. The examination is not easy; and where great disturbances occur under such circumstances, it is natural to be content with that which the previous opinions seem to point out as the real state of things. It is to be expected that future observations will confirm the facts thus stated as necessarily existing.

With respect to other and remote countries, it is difficult to anticipate what the exact position of this series, if it really exists in other parts of the world, will be. That, at this particular period of the globe, it should have been produced in Britain, or here, and in a small portion of Europe, only, is not probable; as it would form an exception of such magnitude and

importance, and as we have no reason, from our knowledge of the other strata, to expect one so singular. We might therefore extend the general analogy, and expect to find the same series, if it should occur widely, following the lowest red sandstone, or at least inferior to the newer one, or to the saliferous strata. But ignorant as we are of the earth at large, and uncertain whether its greater revolutions have been all simultaneous and general, it might be dangerous to make such a rule exclusive. Thus we must be content to wait for further information; and at least till geologists have learnt to distinguish more accurately among the secondary strata, and to give their true places to all those deposits of coal which occur above the saliferous sandstone, here separated from the present series. I must only remark, that as the inferior strata are sometimes absent, and as the superior ones are often similarly wanting where coal occurs, this series may still essentially correspond, in other countries, with that of Britain, even where the same exact order does not take place. It must remain for geologists to extend their examinations far more accurately and widely, before a satisfactory account of the subject, thus imperfectly sketched, can be produced.

In an œconomical light, founded on this view of the coal series, it is now proper to observe, that it must be fruitless to search for coal below the old red sandstone, and, generally speaking, beneath the mountain limestone; as, to mine after primary coal would be a wild project. It is almost equally useless to seek for it in those strata. It is also unadvisable to attempt it, even in countries displaying the upper secondary strata at the surface, where indications of coal do not exist; as it can rarely be known what the superincumbent depth is, or whether, even if that were

· s be present, or, if even pre-
· beds of useful coal. Yet we
· ace; and hence, wherever the
· always possible that coal may
· it will thus be discovered
extensively than it has yet been.
Thus it may exist even be-
· and Africa. And hence we
· treme caution in distinguish-
· the later sandstones.
· ing coal follow necessarily
· connexions. It is superfluous,
· technicalities of miners on this
· s reduced to a simple prin-
· ws will operate as a caution
· n practised by the interested;
· nstrate the value of geological
· of general education, if any
· the higher Public, of the utility
· stries, œconomy, and science.
· er to enumerate a few examples
· ch occur in this series, as it is
The coal of Gloucestershire suc-
· which follows the mountain lime-
· ne: and, after some alternations
· it is followed by a coarse grit of
· and by a similar coal series, suc-
· coarse grit. Over this are placed,
· the red marl, the lias, and the lower
· the limestone. Near Bristol, the
· e deposit is said to be four thousand
· forty feet, containing thirty-one coal
Derbyshire there are enumerated thirty
· from six inches to eleven feet; the total
· coal being twenty-six yards. In this series,
· the magnesian and the mountain limestone,

there are twenty sandtone beds, besides alternations of shales and clays. In the Durham and Northumberland coal-field, forming a mass 4,035 feet in depth, there are said to be thirty-two beds of coal, sixty-two of sandstone, and, towards the bottom, seventeen of limestone; the remainder consisting of shales and clays: a bed, or pseudo-stratum, of basalt being in one place interposed, as an adventitious and accidental rock. One foot and a half is an average of the thickness of the coal beds, and six feet the largest dimension. It is unnecessary to give more examples of the disposition of coal in England.

In Scotland, there are but two coal-fields of this nature; and, as far as I can here venture to mark a difference, it is that the proportion and range of the coal beds in the total series is less than in equivalent spaces in England. In general, the usual alternation of strata succeeds to the red sandstone, and to a limestone analogous to the mountain limestone of English geologists. But this is sometimes absent; so that the coal series lies immediately on the red sandstone. But the strata which follow it in England are here wanting; so that it is the uppermost where it exists; though small portions of the magnesian limestone and of the red marl have been said to occur in some places. I need not give special examples of recorded variations, especially as I am by no means satisfied of the correctness of the observations.

In Ireland, the Connaught coal strata lie, similarly, on a body of limestone of various character, sometimes interstratified with sandstones, and following the lowest red one: the series terminating upwards in the shales and sandstones. In the Leinster district, a similar limestone is said to repose on the granite, and to be followed by a corresponding succession of beds. But I need not enter into further, and sometimes doubtful

enumerations, as they afford no geological instruction; while the information required by the miner demands all the minuteness of local details.

A few words on the geography of coal deposits, as this is found in authors, will not be misplaced; though it is probable that very few of those which exist in the world are known. If, for example, the coal strata of England lie, in the south-eastern tracts, beneath the enormous mass of the superior strata, they may equally exist in many other countries, where, from the position of the strata, their depth, or the want of external indications, they are little likely to be found or sought.

If the British islands possess one of the most extensive deposits of coal yet discovered, that of the Low Countries, including a considerable territory near Liege, is the next in importance in Europe; bearing a considerable resemblance, in its essential characters, as it is said, to that of Britain. It is also found at Marienburg in Misnia, at Pecsvar in Hungary, at Rottenburgh in Silesia, at Bilin in Bohemia, and in upper Styria: and further, in Languedoc, in Artois, and in Auvergne, as well as in other parts of France: being worked in forty-seven departments of the empire, and traced in sixteen others. In America, it has been observed in different places, and wrought in some: as at Cape Breton and in Newfoundland, in upper Louisiana and in the valley of Bogotá. One of the most antient accounts we possess of coal is that of Marco Polo; and it is now known to exist in the province of Canton and in that of Kiangsee, as well as in Tartary, where its use was long ago understood. In the Burman empire, it accompanies the celebrated bituminous wells. In the Waldai mountains it is found near Borowitsch, and it has been discovered and wrought in New South Wales. It is probable that nothing is

yet wanting in many other parts of the world, but knowledge, industry, wealth, and the stimulus of want, to prove that it is a far more common substance than it has hitherto appeared to be.

Now, though I have given but a few of the localities of coal quoted by authors, I have suppressed many more, and ought assuredly to suppress some of these. Many of them are instances of the lignite formation, not of the coal series under review; but the present confusion on this subject being inextricable, I shall suffer the few statements which are proved to require correction, to stand over to the next chapter.

It remains to say a few words respecting the deposits improperly distinguished by the term Basaltic coal, equally applied to the lignites in similar positions. If the peculiarities of these coal fields are highly interesting to the miner, their geological differences are simple and easily apprehended. They are analogous to all the phenomena occurring where trap intrudes among the stratified rocks: the only fact deserving note here, being the peculiar influence which these have exerted on the coal beds. They are found among these, either in the shape of intersecting veins, or of parallel ones, forming pseudo-strata; being accompanied by the usual disturbances, sufficiently described. It is in these cases that coal becomes charred, or columnar, or is converted into plumbago; while the siliceous schists and indurated sandstones which often accompany it, are analogous consequences from the same cause.

An arrangement of the varieties of coal having been given in the Classification of Rocks, it needs not be repeated here. The connexion of its mineral characters with lignite and with peat, are important, both in a chemical view, and as illustrating the natural history

and origin of all the modes of coal. But that comparison could not now be drawn without anticipating the history both of peat and lignite; and I shall therefore defer it till that of peat has been given.

The organic substances connected with coal, are, very predominantly, those of vegetables; as to the last it is indebted for its origin. In some instances, shells occur; as in Derbyshire. While some of these unquestionably belong to fresh water, many are doubtful, and others are thought as certainly to be marine. The genera Ammonites, Orthocera, Mytilus, Unio, Terebratula, and Lingula have been remarked, among others; and even the fragment of a fish has been observed. I have elsewhere pointed out the difficulty of pronouncing respecting the exclusive origin of any shell; though there is nothing in the theory of coal that should absolutely exclude marine remains. The most perfect vegetable remains are found in the shales, though they occur also in the sandstones. Yet if coal often contains carbonized wood, or portions of plants, of which the interior organization is sometimes visible, or so abounds in charcoal that it pervades the whole mass, this will, I believe, be found the case rather in the superior, or lignite coals, than in the series under review.

The progress of fossil botany is as yet so imperfect, and those remains are often so broken and obscured, that not much has been done towards their effectual description and arrangement. For that information which does not fall within the plan of this work, the reader must be referred to Sternberg, Schlottheim, Brongniart, and others, or to the abstract of Conybeare and Phillips. It is sufficient to remark, that plants of aquatic habits seem to prevail among them; the predominant remains being those of gigantic vege-

tables resembling equisetums, accompanied by others analogous to ferns and lycopodiums, and, as it is thought, to palms; with some which appear to possess no exact living analogies. The fluted and the scaly stems and trunks, distinguished by the terms Lepidodendron and Syringodendron, are the most remarkable, as they are the most obscure. The genera seem to be very limited, as far as they can be determined from such imperfect specimens; but it is imagined that the species exceed three hundred, or approach to four. How far they may be considered as tropical plants, I have already had occasion to enquire; while, when it is said that at this period of the earth no dicotyledonous plants existed, and that the chief vegetable creation was a cryptogamous one, we cannot but be surprised at the minute progress which philosophy has hitherto made among the cultivators of this science. The Geologists of a future world, whose researches may begin and end in a rock formed out of the Sheppey clay, will perchance determine, under similar reasoning powers, that the world produced no plants but hazels.

In the sandstones, the most frequent vegetable appearance is that of concretions of sand bearing the impression of the trunks just noticed; and, in these cases, while the woody matter of the tree has disappeared, the bark is sometimes converted into coal. These are often compressed, as if by the superincumbent weight, and are also recumbent; but, there have also been found remains of trees similarly changed, in an erect position, with the branches attached.

Such are the organic appearances connected with coal; all of them bespeaking a terrestrial, not a submarine origin, for the general series in which it is found. Their aquatic nature equally indicates the

growth of these vegetables in low moist forests, in marshes, or on the borders of lakes or rivers. In the repetition of different strata, we see the successive deposition of earthy matters of different natures, afterwards consolidated into sandstone or shale, or else remaining unconsolidated; while the repetition of carbonaceous beds, no less than the deposition of vegetable strata alternating with the laminæ of the shales, shows that successive generations of plants had followed successive depositions of earth. To the same circumstances of repose, the solution of soluble earths, pressure, and, it is possible, to heat, we must attribute equally the consolidation of the rocks and the conversion of the vegetable deposits to coal, as I shall hereafter explain more fully.

Although the vegetable nature of these remains thus indicates the terrestrial origin of the series, the subjacent limestone contains marine remains. These strata then, as I remarked under former general views, have been formed under the sea, of which the bottom must have been elevated prior to the deposition of the coal beds. That the vegetables could not have been transported from their places of growth to that position, is no less proved by the integrity of the most delicate specimens, than by the erect trunks of trees abovementioned. Yet though assuredly formed on the supramarine land, it may still seem difficult to account for the great thickness of many deposits, and for the frequent alternations of rocks and of vegetable matter. The existence of deep lakes, at some period and under various modifications, is necessary to explain the phenomena; though it may be difficult to conceive the exact details of the changes, and the condition of the surface necessary for their production. In the history of the later lacustral formations there are analogous

difficulties; yet, in this case, the necessity of similar changes is equally demonstrated. But if, as I formerly suggested, a gradual subsidence of the land during this condition of the earth is admitted, the difficulty respecting successions of any depth, ceases, as unequal subsidences would aid in accounting for unequal depths: while such a possible state of things is supported by the phenomena of Banda already noticed, and by much more that I need not here repeat. It is not difficult to explain the presence of marine bodies, or even of complete marine strata, if such there really are in any coal series. It is merely to suppose an æstuary instead of a lake; and it has already been shown that the mode of deposition, and the alternation of the substances, are at present similar in both.

From the marine origin of the strata above the coal series, it has formerly been shown, that those parts of the surface which were once above the water, and which received the deposits of land vegetables, have been subsequently immersed beneath an ocean during the period of unknown, but great duration, requisite for the accumulation of such enormous masses. The last change restored to the surface of the earth, and often to great elevations, those strata which had once before occupied it; accompanied by all those which are found above it, and by many of those which lay below. Such changes could not have taken place without violence and derangement; and to them we must attribute those fractures, dislocations, and flexures of the coal strata, no less than those of the other rocks which have undergone analogous changes.

The œconomical management of coal strata, and the art of mining them, form a subject foreign to the objects of this work; and they may be found in numerous treatises written for that end.

CHAP. XLIII.

Lignites.

In conformity to an accepted arrangement, which I do not approve, yet do not at present choose to depart from, the present chapter includes every combustible deposit following the magnesian limestone. It comprises many which are undistinguishable from the former coal, both in general disposition and in mineral character, together with the several substances which are lignites in the mineral sense of that term: the latter forming an important object in the theory of coal, as being the link by which it is connected with peat.

The gradation of geological relations from the "independent" coal to the most superficial woody lignite in the upper alluvia, and thence to peat, is sufficiently perfect; while from that through the old red sandstone, we can pursue this gradation into the primary strata. But the mineralogical or chemical gradation is even more complete: and, in this respect, the woody lignites hold a station more nicely intermediate between coal and peat; some of them approaching as nearly to the submerged wood of peat in chemical characters as in their appearance; while, in both these respects, there are varieties at the other extremity of the series, scarcely differing from coal, and finally identical with it. I must however remark, that while almost every ligneous substance found beneath alluvial soil, and bearing marks of bituminization, is here ranked as a lignite, I have found it more expedient to class with peat the submerged wood of the most recent alluvia, even though it should be slightly bituminized; on account of its different connexions with that substance.

While the superior antiquity of the woody lignite to

peat is proved by geological position, it is also inferred from the bituminization of the vegetable matter: their production too appearing to have long ceased, while that of peat is matter of daily observation. Yet the chemical nature of the former does not always correspond accurately with their antiquity; while the submerged wood of peat occasionally presents marks of bituminization, as just hinted. This difficulty, common throughout mineralogy, among associated substances, is an important fact in the history of these combustibles, though it may be a blemish in a mere arrangement. Still the main distinction must be sought in the fact of bituminization; of which peat at least, except from the casual admixture of bitumen, presents no traces. And though these lignites may retain the marks of organization, so far, it is said, as to allow the difference between the monocotyledonous and the dicotyledonous plants to be perceived, they are generally flattened or compressed; as the submerged woods rarely are.

If the boundary of the woody or organic lignites towards peat is thus somewhat indefinite, so is it indefinite towards coal. In a merely mineral point of view, however, the most obvious distinction would seem to consist in the mechanical rather than the chemical nature of the specimens; at least of those at the immediate point of transition. In most cases, the woody lignites retain some marks of the vegetable form, though sometimes found in a pulverulent state: whereas coal assumes the shape of a rock, even where it still contains the remains of vegetables. But this subject must be more strictly examined under the head of Peat, where the chemical relations of the whole are brought into comparison. It is sufficient that I have

here noted the transitions by which this production is connected with coal. These remarks, however, apply solely to those substances considered as minerals: the geological distinctions are sufficiently marked, as it is plain, that under the present arrangement many of the lignites are, in a mineral view, coal.

The varieties of the Coal lignites require no notice; and those of the woody ones enumerated by mineralogists, are brown, or Bovey coal, surturbrand, jet, and Cologne earth, or pulverulènt lignite. Of these, however, the three first are not defined species, since they rather tend to graduate into each other; as Bovey coal, becoming darker and more bituminous, passes towards surturbrand, and this becomes undistinguishable from jet. If the others are not always powdery, they are at least sufficiently tender to be easily reduced to that state. To these I should add the casual specimens, of no decided character, which occur among the various strata; with the fragments of vegetables and fruits generally described among the organic substances. The origin and theory of the whole are similar; but as they are not of sufficient importance to require a separate detail, they may be considered as casual fosssils in the several strata where they occur.

There are three obvious situations, sufficiently distinct, in which lignite occurs; namely, in alluvial soils, under stratified rocks, and connected with rocks of the trap family. But the importance of some of the deposits requires that the stratified rocks should be distinguished by their more rigid geological connexions. I shall here omit the coal which occurs in the red marl, since it was already noticed in the last chapter. It ought, indeed, in strictness, to rank here; but being unimportant as a deposit, it is sufficient to

have thus named it among the following more conspicuous examples of this substance.

The lowest in order is that which belongs to the lias and oolithe series, which, for the present purpose, may rank as one. Though some geologists have been unwilling to admit of more than one such deposit beneath the chalk, there can be no question that there is a second, which may be referred to the green sand. The third is situated above the chalk, in the plastic clay, and the last is that which occurs in the antient alluvia. I might indeed refine on this division, by separately enumerating those which have been described in the red marl, in the muschelkalk, and in other positions, through the whole series above the magnesian limestone, as we might also find other deposits in the strata above the plastic clay. But such refinement appears unnecessary, except for local purposes; and it will be sufficient to have thus indicated such less important and marked examples. To these must be added those which, though not forming extended deposits, are important from their characters and positions, while not falling into any of the preceding divisions. Occurring among the trap rocks, they have been called basaltic coal; but as this term, equally applied to the ordinary coal series where interrupted by trap, has produced confusion, the name of basaltic lignite is preferable. Volcanic lignites, such as that of Iceland, need not be distinguished from this kind.

From the confusion which has been made between the coal beds here classed with lignite, and those of the proper coal series, it is not possible, or not safe, to quote examples in illustration of some of them; nor is it even in my power to produce adequate descriptions. A more perfect set of observations is yet wanting, and, till then, this sketch must be doubtful or

imperfect. Yet, by thus giving the geography of the chief known lignites, these places will form points of reference in case of error, and in lieu of the descriptions which are yet wanting. Future and more accurate geologists will hereafter be enabled to separate ill described cases from the genuine coal, and complete what I must leave imperfect. It must always be remembered, that as these deposits can be distinguished by the accompanying strata, so, with strong resemblances, there is this distinction between them and the true coal series, that whereas the latter rarely contain marine remains, these are common in the lignites.

Deposits of lignite coal occur abundantly along the western declivity of the Jura, in the south-west of Germany; abounding chiefly in Westphalia, and being wrought in the Buckeburg, as they are also in Coburg and to the east of Spittelstein. Near Quedlinberg and Pirna, the same substances are scattered through the sandstones. It appears that, at Coburg, they belong to the quadersandstein, as seems also the case in other parts of the tract above mentioned; so that we must perhaps adopt a division prior to that of the lias and oolithe. In Istria, they occur in the oolithe abundantly, passing into coal at Carpona and in the island Veglia, where they are wrought for the use of the Trieste steam boat. It is to the same series that we must refer what is called the Kimmeridge coal of England, consisting rather of bituminous shale than of true lignite, and also that of the Cleveland district of Yorkshire, Such too is the coal field of Brora in Sutherland, of which the singular position on the granite has been noticed elsewhere, and further, that of the Western Isles of Scotland, occurring in the lias, or in that and the oolithe conjointly.

These deposits call for a somewhat more particular

notice; not only because they are "national" ones, but from their instructive difficulty and singularity: while the geological student may learn a much needed lesson, if, in noting the confidence and ease with which they are now descibed by those who, formerly, could neither see nor understand them, he shall extend his views of morality, and also reflect that the fame built on the labours of others is as perishable as it is little creditable. On the western coast of Scotland, there are the scattered fragments of this series, discoverable, often by the most slender and obscure indications, in different parts of Sky, Rasay, Mull, and some other associated islands, and, on the mainland, in Morven; finally terminating, southward, in a far remote fragment near Campbelltown. To add to the obscurity produced by separation and distance, they are every where, except at the last place, entangled in trap, and often deeply covered by it, so that they can only be traced, in some places, beneath it, by the most slender and limited indications. And in Morven, such is the result of this interference, that minute and far insulated beds of coal are found perched on the summits of conical mountains of gneiss, covered by masses of trap; remaining as beacons to indicate what has been removed by posterior causes, to add to this difficulty. The details will be found in my account of the Western Islands; but the general deduction here required is, that there had once existed on this side of Scotland, an extended deposit of the lias and oolithe series, containing coal, and that these have been overwhelmed by trap, and, further, separated as they are now, by other causes on which I need not here again enter. On the east side of the same country, the similar deposit, skirting the shores of Sutherland, has escaped the interference of trap; but in all other respects the

series is the same; while the scattered fragments extend further than I originally thought it necessary to say; not foreseeing that my own intended omissions in Scottish geology were ever to become a means of discovering in what the knowledge of others consisted.

Of the lignite which occurs at Frankenberg, the geological position is doubtful; and it is found also in Thuringia, at Pernitz near Vienna, at Wolfseck, near Haagen, and in many other places, where it is wrought for coal; as is the case in Bohemia and Hungary; the mines of Buda, in particular, being remarkable. I cannot discover that the geological positions of these, and of some others which I need not quote, are clearly understood; but it is certain that some of them have been mistaken for the true coal series. The same error seems to have been committed respecting that of Bornholm, of which the correspondences extend wide over the north; as is also true of that at the foot of the Apennines, which occurs in the Vicentin and Veronese, at Castelnuovo, and elsewhere, accompanied by trap. Some lignite beds occurring in certain parts of America, seem also to have been similarly mistaken; but I need not prolong the enumeration of localities among such obscure examples. If I name that lately found in the north, at Melville Islands, it is chiefly on account of the presence of such a substance in regions, of which the vegetation is now so cramped.

It seems now admitted by Brongniart, to whom I m indebted for these foreign examples, that the supposed coal of the south of France is a lignite formation, occupying a higher part of the series than the last examples, and lying in the green sand deposit. There are extensive mines of this in Provence, about Marseilles and Toulon, where twenty-eight beds are

wrought; and it abounds also at Soissons, Epernay, Laon, St. Paulet, and some other places in France. That of Annecy in Savoy, which is also wrought for coal, is referred to the same position: as is that of Putzburg and Lobsann, and that of Cologne, so well known and so often described. The principal deposit here, is thirty feet in thickness; and this locality is remarkable for its peculiar pulverulent lignite, so well known in painting.

The immense deposits of Styria, and those found in the middle of the Alps, are supposed to occur chiefly in the sands of the plastic clay; yet some examples of this nature appear to belong to a purely fresh water or lacustral origin. Those which abound in certain parts of Germany, as near Cassel and Meissner, are conceived to appertain to a formation of this nature, though lying in contact with the magnesian limestone; a situation, as I have formerly shown, not incompatible with such a geological position. Those also which are found in the basin separating the Alps and the Jura, at Vernier, Paudex, Vevay, near the lake of Zurich, at Oeningen, and elsewhere, including all the steinkohles of Switzerland, appear to be the deposits of a fresh water lake in antient times, as might be inferred from former remarks respecting this great locality. Those of Sheppey, the Isle of Wight, Sussex, and other analogous places in England, must, on the contrary, be referred to the marine deposit, the plastic clay. Thus the lignites above the chalk would admit of being divided in the manner which I formerly proposed as to the tertiary deposits; as they must be hereafter, when geologists shall have investigated these with more accuracy and discrimination.

Having thus given such localities as seemed sufficient for examples, or for indicating the general posi-

tions of these deposits, with the errors which have been committed respecting them, I may add a sketch of what little is known with regard to the general characters of each class or division.

The lowest deposit, or that of the oolithe, which may include all from the magnesian limestone upwards to the green sand, is more frequently akin to coal than to the woody lignites, though the latter substances occur also in various forms. In some places, it exists in the strata in groups of different dimensions, or in scattered fragments, or else in thin and partial beds. In others, it forms regular beds of coal, of various, and sometimes of considerable thickness; and when these alternate with the shales, sandstones, and limestones, of the series, the superficial aspect is so much like that of the regular coal series, that it is not surprising if it should have been mistaken for that deposit. This coal however is generally, or perhaps always, accompanied by woody lignites, commonly in the state of charcoal, dispersed through the accompanying rock. In the example in Sutherland, one of the beds is three feet or more in thickness, while another does not exceed an inch. The animal remains hitherto discovered are not numerous, but they are thought to be marine; and hence a distinction has been attempted between this and the proper coal series, respecting the truth of which I must enquire hereafter. It is however probable that the supposed existence of marine shells in this last, has generally arisen from confounding it with the lignite coals under review. If I name madreporites, ammonites, belemnites, ostreæ and echini, I need not proceed with this list, since the shells to be expected are those which belong to the calcareous series itself.

The Lignite, as it occurs in the green sand, is said

to exist rather in heaps of fragments than in proper beds; but the descriptions of individual cases are imperfect and unsatisfactory. In the Isle D'Aix, the accompanying substances are sands, marls, and cherty flints, with quartz, agate, pyrites, and resinous substances. The wood is that of dicotyledonous plants, and it is said that no palms have been found. This wood is sometimes silicified, at others fibrous, or in the state of jet. Fuci also are said to occur; and the shells are all marine, consisting of nautilites, pectinites, gryphites, and others. With respect to these fossils, the same general rule may be applied as in the former case.

The deposits of Lignite found in the strata which succeed to the chalk, or in the tertiary formations, have recently experienced considerable attention, particularly in France; though our knowledge of them is still necessarily limited. Their geological connexions suffice to distinguish them from those which belong to the inferior strata, or to the alluvial formations; and their origin and causes are similar to those of the animal remains in the same situations. It is unnecessary to say that this lignite may occur in any of the strata of such a series; and equally unnecessary, here, to give more than this general indication; as the peculiar cases must be sought in local descriptions. But in addition to the accompanying strata, they are, in different places, attended by quartz, agate, calcareous spar, sulphate of strontian, pyrites, and hydrated iron; together with amber, and imperfectly bituminized resins, such as those of Bovey and Highgate.

The lignites themselves are sometimes fibrous and woody, while, at others, they pass into jet, and even into coal; being, further, occasionally silicified. Leaves and fruits occur, together with the woody

stems of dicotyledonous and monocotyledonous plants. The hitherto imperfect arrangement of fossil vegetables, has referred them to terms, rather than genera, under the names of Carpolithes, Phyllites, Lycopodiolithes, Palmacites, Endogenites, &c.; nor need I quote the more minute distinctions under which they have been arranged. The large list of fossil animal remains will be found in the often printed catalogues.

The last division of the lignites is that which occurs in alluvial soils, and which seems necessarily limited to the more antient alluvia. The scattered specimens, of various character, dispersed in the upper alluvial portions of the tertiary strata, must be ranked in this division; but we are not well furnished with recorded examples of this nature. I must follow the prevailing opinions, in referring the well-known case of Bovey to this division, though not satisfied that it is a real instance of an alluvial lignite. For want therefore of satisfactory observations, we can only conjecture generally what the characters of such a deposit ought to be, and what are the accompanying substances. It is to be suspected that many of the supposed alluvia, containing amber and jet, described by authors, are rather cases of the tertiary strata beneath: the sands perhaps of the plastic clay, or other portions of these deposits, having been mistaken for alluvial formations.

There is another difficulty respecting the recorded descriptions of the alluvial lignites, lying at the opposite extreme. Among the numerous examples of forests submerged under alluvial soils, observers have not often enquired whether the wood was a true lignite, or was only that unbituminized substance which, essentially, is but a mode of Peat: being unacquainted with the chemical distinctions, which I first pointed out in the Geological Transactions. But in the un-

questionable cases, the wood is flattened, as if from great pressure; possessing also those peculiar chemical properties by which the lignites are distinguished from peat. In such situations also they vary in quality; containing more or less bitumen intermixed with the peculiar compound which constitutes peat; while those which are most deeply situated are commonly also the most highly bituminized. The case of Bovey offers examples of this nature, if it be really one of alluvial lignite; since the different strata are separated by the loose matter which fills this valley, and the more perfect lignites occupy the lowest positions.

The depth of the superincumbent strata, and the number of alternations in these cases, present considerable variety; but the recorded observations do not yet admit of any general conclusions deserving of much regard. The total depth at Bovey, is said to be seventy feet; this space including all the lignites together with the alternating beds of clay. In Iceland, the lignite appears to be generally much more superficial, and is found in the form of boards; as if produced from the trunks of trees flattened by pressure. This is the variety to which the name of Surturbrand has been particularly applied. That of Bardestrand is found on a hill of moderate elevation, beneath strata of sand and clay alternating with peat; and here, as at Bovey, the upper beds are imperfect, the middle intermediate in quality, and the lowest most complete. At Arnafiord, it is accompanied by shale, containing bones, with fragments of branches and roots. I need only add, that the position of jet is sometimes analogous.

It thus appears that the lignites buried under alluvial soils, occur in the several forms of brown coal, or common woody lignite, pulverulent lignite, or Cologne earth, surturbrand, and jet. To whatever different cir-

cumstances these variations may be owing, the differences, in a chemical view, are very considerable, and imply either a longer exposure to the causes by which the changes have been induced, or a much more energetic action of these. Yet, considering the numerous known examples of antient alluvia, the rare occurrence of lignite among them is a remarkable circumstance; since we cannot conceive that small portions only of the surface were covered with trees at the period of these deposits. Modern occurrences may perhaps however explain it; since in the numerous deposits from rivers, or in the changes on sea shores, it is only in a few cases that we find trees deposited in any conspicuous quantity.

It may be asked, perhaps, why deposits of wood of a high antiquity do not always assume the character of coal, when antiquity alone has been supposed sufficient to produce the completely bituminized state of lignite. But, in fact, there is often little difference between the chemical nature of such antient lignites and of coal; as is true even of jet, not always among the most antient in position. But as I have already said, the true distinction of coal is its mechanical texture, or its rocky, or stony, character, and it is easy to imagine how that might have been induced under peculiar circumstances in which some of the lignites may not have participated. It will also be found, that many varieties of coal, burning with a peculiar fetid smell, of which I first pointed out the cause, derive that property from participating in the chemical nature of the woody lignites; containing a portion of that unchanged peat from which the fetid smell of these lignites is derived. Such coals are, in fact, mixtures of lignite and coal; if such an expression may be used where two substances pass into each other by imperceptible transitions; the form

and structure justifying the name, either of coal or of lignite, as it may happen, while there is an identity or resemblance in the chemical characters of both.

The last geological situation in which the lignites occur, is among the traps; while they have been incorrectly examined and described, as the facts have been also misapplied, to support an hypothesis respecting these rocks. These have been called bituminized wood, and basaltic coal; but I have already given reasons for preferring that of basaltic lignites. They sometimes retain, in a considerable degree, the chemical nature of vegetable matter, or peat; giving out, on distillation, the particular volatile products by which the other lignites are distinguished, while, at others, they are converted into perfect coal. It is in the former case chiefly, that they retain the vegetable form and structure; but they do not always entirely lose it, even when they have become coal. They sometimes occur in insulated fragments, or as portions of trees; at others, they are accumulated in a particular place, so as to form small irregular deposits; in which cases the vegetable form disappears, or becomes very obscure. When these are of considerable size, they often put on the rocky character with the chemical nature of coal, and are sometimes partially wrought for œconomical uses. In one instance, in Mull, the specimen of lignite is a large portion of the trunk of a tree; the vegetable texture being perfectly distinct, but the substance so tender as to fall into powder under a very slight force, like some of the specimens from Cologne.

It is necessary to state accurately the connexion between the trap rocks and the accompanying lignites, because this has frequently been used as an argument against the igneous origin of the former, on the one hand, while, by another party, it has, under equal mis-

apprehension, been supposed to prove that origin, and further to justify an analogous theory respecting common stratified coal. But it will be seen that the facts prove nothing on either side; while, the dispute is but one specimen out of many more in geology, founded on bad observation and similar reasoning.

The lignites in question are often found in the conglomerates which accompany the trap rocks, commonly known by the name of Trap tuff. If I need not here describe the varieties of these, I must remark that they often contain rounded materials; proving some transportation, or motion, previously to their consolidation. It is easy to understand how fragments of wood may have been introduced among such materials, when loose, and how the whole mass may have been consolidated together. But this consolidation has not resulted from fusion, or from any high degree of heat; as the very fusible sand in them could not have retained its loose texture in such a case. Although covered therefore by crystalline traps, as they often are, the included lignites have escaped combustion under their protection; while the error of one party has been, not to see what the real situation of the lignite was, and, of the opposed one, to suppose the tufo a rock of fusion; ever unable to see but one cause for every thing, and that cause, fire. This fact, therefore, does not prove that the solid traps have not been in fusion, but merely that the tufas have not been so formed; of which indeed, there is sufficient other evidence. But, for the other party, it does not prove that the wood has been bituminized by fire; from the action of which, like the surrounding materials, it has been exempted; while chemical reasons will hereafter be adduced to show that vegetable matter is not bituminized by the action of fire alone.

In other cases, the lignites of trap occur in veins or

chasms in the solid rock; as is the fact respecting the specimen in Mull, remarkable for the erect position, as for the magnitude of the fragment. If, in these instances also, the lignite has been said to be contained in the solid trap, this is another bad observation; as the vein is always filled by a tufaceous conglomerate, wherever these cases have occurred to myself. And this, I doubt not, is the fact in all the recorded cases; where, either from superficial examination, or ignorance, or from that tendency to overlook circumstances which disagree with a favourite hypothesis, this important circumstance has been neglected. In whatever manner such tufaceous cavities have been formed, it is evident that they have been exempt, like tufaceous beds, from a degree of heat capable of fusing them; and thus have the accompanying lignites escaped destruction; if indeed destruction be that necessary consequence which has been supposed. Nor is there any difficulty in seeing how a fused rock should have entangled a portion of a conglomerate in this very manner; as such a vein also, formed at first in an open cavity, might be sealed up by fresh eruptions of fused matter.

In the last position in which I have found a lignite in trap, it has appeared to be imbedded in the solid rock; which, were this truly the case, might present a difficulty as to the theory of this family. But when strictly examined, it will be found that the substances in the immediate vicinity of the specimen are not crystalline, but that some portion of shale surrounds it, or that it lies among earthy fragments of those strata which have, by their partial fusion, produced the principal mass, as other portions have been entangled in it during its state of fluidity. And the unaltered, or slightly modified state of those substances, proves that the heat has not been sufficient to effect the en-

tire fusion and ultimate change of the original strata into crystalline trap ; so that, here also, the lignites have equally escaped.

Even however if lignite should be found surrounded by a crystalline trap, it does not follow that the rock has not been in a state of fusion, or at least of softness, sufficient to enable its parts to assume a crystalline character. The siliceous schists beneath basalt often assume that concretionary structure which proves a softened condition of the same nature ; and, in such cases, shells are often found entangled in the mass, sometimes deformed by pressure, as the lignites themselves are, yet retaining their integrity, with much of their original characters. Neither is the bituminous matter of the strata dissipated in such cases ; since, the associated limestones and shales are often highly bituminous. Charcoal also, I need not say, is indestructible by heat, when protected from air ; and though sometimes altered in chemical character by the loss of its hydrogen, it still retains its form. Hence then, even the woody lignites might remain surrounded by fluid trap till it had cooled, as coal also unquestionably does, where the ordinary coal strata are found in similar circumstances. If this particular case has not occurred in trap, it is known to have happened with lava, so that the difficulty is completely removed. In Italy, trees have been found entangled in perfect lavas, having burnt out where there was access of air; and in the isle of Bourbon, the trunks of palms have thus also been observed wrapped in lava; the stony matter having further penetrated the fissures so as to have assumed their shapes.

Hence then might the lignites of trap often preserve their vegetable organic character, together with their chemical nature, in considerable perfection; while, in other cases, they might be entirely converted into

coal. In the lignites of Meissner, the woody kinds are actually changed into coal when they are in contact with basalt. I may now barely say, that the degree of pressure may have been sometimes such as to prevent the entire dissipation of the volatile matters, and that the degree of heat and of pressure, having been inferior to those required for the fusion of the lignite into shapeless coal, the vegetable structure has been preserved, as it would have been in charcoal under similar circumstances; while the form has perhaps also been preserved through the protection afforded by unfused fragments or earthy matters entangled together with it in the trap.

I have only to add on this subject, that as long as a sect existed to maintain that all trap rocks had been formed under the sea, every lignite thus connected with them was supposed to have been entangled in the same place. The problem was sufficiently difficult; yet not conspicuous among the other difficulties consequent on this hypothesis. But as I have shown that these rocks have been produced under the same variety of circumstances which attend volcanoes it is easy to understand how they should have entangled fragments or deposits of wood imbedded in terrestrial alluvia, just as modern volcanoes have done. And it is further plain, that, as in the case of Meissner, the irruption of trap into strata already containing lignites might have produced similar appearances; the clays or marls undergoing the changes which commonly result from this cause, while the vegetable or coaly substances would thus become involved in the trap itself, or in the rocks which it had modified.

These enquiries respecting the much misapprehended nature of the basaltic lignites having involved the theory of that division, it only remains to enquire into that of the older and the alluvial ones; and while

I cannot admit that which has been hitherto received as satisfactory respecting the former, I must regret that I cannot make my own views as clear and convincing as I should desire; for want of sufficiently accurate and extensive observations.

With respect to those beneath the lias and oolithe, the explanation seems that which is equally applicable to the coals of the old red sandstone and mountain limestone. Transported fragments may account for some; while as I shall soon show that beds of peat are produced by marine plants, there is as little difficulty in accounting for partial beds of coal in these deposits, as for the greater ones in the regular coal series. But this theory will not apply to the deposits of coal in the oolithe and the green sand; so often equalling in extent and importance those of the true coal series, while also resembling them in so many other particulars. Nor can I see that the received theory of transportation will account for all of them; while it must be recollected that this is but a repetition of the same thoughtlessness or ignorance which had attempted to explain the great coal series in a similar manner, and which I hope the present observations on the whole of this subject have shown to be unfounded, even without a formal refutation.

The imbedded plants are chiefly terrestrial; and they are too often deposited in the same manner and perfection as in the great coal series, to admit of the belief in transportation. They must have been preserved where they fell: nor indeed could aught else account for accumulations capable of forming such beds of coal. He who can imagine vegetable matters, of whatever nature, transported from the land to the sea, there sunk, there so often preserved in their characters, and there accumulated in partial beds, *must* have forgotten, as usual, to enquire of causes;

of those daily and visible actions, of which former ones could but have been the antetypes. If the accompanying shells are said to be marine, they offer no objection; when I have shown the difficulty of assigning this exclusive origin, and when also it is remembered that the theory required such a belief, or assertion. And though they were so, the formation of coal in marine æstuaries would explain even this invented difficulty.

I must therefore conclude, that the more extensive deposits of lignite coal, in whatever position beneath the chalk and above the red marl, have been produced under circumstances analogous to those of the great coal series, while apparently on the margin of a sea or in æstuaries, rather than in inland lakes. But there are no marks of a revolution with succeeding reversed deposits, as in the case of that series; and thence another explanation of their present position beneath consecutive and parallel strata is required. This, I think, may be sought in what I have already suggested as an explanation of the great depth of the true coal, and of which the proofs have often already appeared. It is that gradual subsidence of land which admitted the sea to rise above any given portion, while the new deposits, in such a case, must have maintained that parallel order, which, under any sudden and perfect revolution, would have been impossible. If, in these greater deposits, there should be local or occasional portions, formed of marine plants or transported materials, they do not affect the general theory, since they are explained in the same manner as the similar ones in the inferior positions. To say that a subsequent general elevation of the entire secondary series brought the whole to their present places, is but to make an unnecessary repetition. And more minute

and accurate observations than have ever yet been made, but which the present new views will render easy, must determine whether any modifications of this theory will be required for the separate cases of the oolithe and the green sand.

There is little to add respecting the lignite deposits in the tertiary strata and the alluvial formations; or at least the reader ought not now to require explanations of these. A stratum of peat in the bottom or on the margin of an antient lake is now a bed of lignite in a lacustral series; and the marine one of an existing æstuary is the type of a lignite in the plastic clay. The lignite beds of a marine deposit now remote from the present ocean is a submerged Lincolnshire forest; and if there are scattered lignites in these several situations, there is antient transportation to account for them all, while the type is seen in the floats of wood buried in the alluvia of the great American rivers. And such events, in antient times, may also account for some of the lignites in the secondary strata, yet never for those which contain fragments deposited in a regular manner. The alluvial lignites may either have been overwhelmed forests or peat bogs, or they may have been transported and covered, as in the recent cases just alluded to; while their dates and circumstances must be regulated by those of the alluvia. Volcanic ones may be of many ages; while it must not be forgotten that volcanoes erupt tufo and mud as well as lava, and that thus have the papyri of Herculaneum become lignites, approaching to peat, if not pure peat. And whether these more recent ones are to be coal or woody lignite, depends on their ages chiefly, if also possibly on other circumstances; while the further chemical facts necessary to this theory will appear in the next Chapter.

CHAP. XLIV.

On Peat.

Though peat generally occupies the surface, it is sometimes covered by alluvia, as it occasionally also alternates with them, from causes sufficiently obvious. Inundations often deposit beds of sand and gravel in lakes and æstuaries or on their marshy margins, as their distant repetition produces successions of this nature; while the same thing sometimes happens on sea shores, from the blowing of sand, as in Holland, where the gradual rise of the land, from a distant period, can be traced to this cause. Nor is peat limited to the land. Independently of that which is of marine origin, there are many extensive submarine tracts, on our own coasts as on those of the opposed continent, which have resulted from that subsidence of the land described in a former chapter. If I need not note the topography of that which occurs over the whole world wherever the temperature is not too high, the flat tracts of Holland and the Baltic present the largest continuous extent in Europe; while, in our own islands, it abounds most in Scotland and Ireland, in which last, a recent survey has reported a million of acres of "bog."

Origin, Nature, and Varieties of Peat.

He who has read the volumes written on this production, has discovered that it is easy to write largely on a subject without elucidating it, and that the most incapable is always the most interminable writer. It would be a waste of time to examine the mixture of ignorance and mystery by which every writer, without one exception, has laboured to obscure a subject so

simple that it seems impossible not to have understood it: the best answer to the whole will be a simple detail of facts.

Peat is produced from the ligneous matter of decomposed vegetables, yet only within certain limits of moisture and temperature. But the former admits of considerable latitude; since it is generated under water; and on the drained declivities of mountains. The range of temperature cannot be exactly assigned; because, in a hot climate, it may be produced under water, when it would not be formed on the soil in the same place. In the tropical regions, the decomposition of vegetables is so rapid and perfect, that no peat is formed in these situations, except in elevated places; while, in the colder climates, it occurs even at the level of the sea. I formerly used this fact as an argument against the imaginary tropical nature of the plants of the coal strata.

The varieties in the quality of peat depend chiefly on the situations in which it is formed, as these relate to moisture and temperature, and on the nature of the plants whence it is produced. Rejecting the distinctions of former writers, equally futile and insufficient, it may be divided into six kinds, namely, Marsh, Lake, Forest, Maritime, and Transported Peat, though the limits of some of these are not always defined. The subordinate distinctions, from intermixture of situations, variations of drainage and temperature, differences of the original vegetation, extent of decomposition, and intermixture of earths, do not here require notice.

In the simplest cases, Peat forms a single stratum, on the alluvial soil or the naked rock; while, in others, it alternates with sand, gravel, or clay, or with marl, or with the beds of shells whence this originates. The latter case occurs in lakes and æstuaries, or in the plains of tardy rivers; and thus it is sometimes deeply buried

under an alluvial soil. Such peat was that of the original marsh, or lake, in such a place; while the alluvia which buried it have, in some cases, prevented its renewal, by producing a non-vegetating soil, or one which has been brought into pasturage or cultivation; as, in others, successive marshes and productions of peat may have followed successive deposits of alluvia. And if alternating beds of marl or shells indicate a former lake more especially, pointing out not less its antient extent, so do such beds, when of marine origin, prove those changes in the mutual boundary of the sea and land to which I have just alluded.

Mountain peat occurs wherever the drainage is rapid and perfect, and is therefore most common in mountainous countries, though not thus limited. It is generally incompact, varying in thickness from a few inches to a foot or two, and rarely much more. In an agricultural view, it is often very important, from its great extent, and the facility with which it is brought into cultivation, especially when lying on dry moorlands; though it is generally a worthless fuel, from its incompactness, except under the destructive practice of paring, as turf.

The variety of extent and situation occupied by Marsh peat is very great, since it constitutes large plains and the smallest mountain bogs, and occurs also on the margins of lakes and æstuaries; being, in the latter cases, often united to lake and to maritime peat, by transition, inasmuch as the shoaling of each first produces a marsh. Hence considerable variations, and also much additional confusion of character, from the variety of the surface at different stages of its progress; whence its transitions are from the most compact peat of lakes to the most lax of mountain declivities, as the drainage has differed at different places

and periods. Thus also it often constitutes the well-known bog; remaining semifluid beneath, while bearing, above, a matting of half decomposed vegetables, or partial firm spots of living rushes or other plants. This rush-turf, as it is called, is generally an imperfect peat, and often also covers a stratum of a perfect nature, resulting from that drainage which is the solidification of a trembling bog. This is the peat in which the Sphagnum palustre abounds, being its natural soil; but extreme inattention or absolute ignorance alone, could have assigned the origin of all peat to this moss, as has been done by numerous writers of presumed reputation.

I may here remark, once for all, that every plant existing where peat is produced, contributes to its formation, and each in proportion to its ligneous matter. Those of our own country ought to be too well known to require enumeration; while, as they must differ in every climate, a catalogue would be equally tedious and useless. If our own peat is the produce of our lacustral and marsh plants, that which laid the foundation of coal was generated by those whose analogies we trace in the present tropical ones. That there have been writers who considered peat a living vegetable, is but conformable to all the rest of the former philosophy on this subject.

Lake peat presents an additional interest, arising from that obliteration of lakes of which it is an auxiliary cause. But two distinct sets of plants are here engaged, under two distinct processes; so that the entire proceeding is more complicated than in the preceding cases: while, seeing the final cause, we cannot but be struck by contrivances to which, were they human, the term ingenuity would most justly be applied. The shallow portions produce floating plants,

such as the Potamogetons, that subside after flowering, to form a vegetable stratum, which receives constant additions from the Scirpus, Lobelia, Subularia, and others, destined, in another way, to the same office. These also, detaining sand and clay, gradually shoal the margins, so as to give a place to the semi-aquatic plants, bulrushes, reeds, and others, which, advancing from the edge, gradually generate a marsh, so as to form a place for a third class, till the process of solidification is completed. If, at other times, this last operation alone takes place, the final result is, in any case, the formation of lake peat, passing into that of marshes; and thus finally producing those extensive flat bogs, the nature and origin of which have been so much misapprehended by naturalists as well as agriculturists. I need not have noticed this error, but from its practical importance to the latter; negligent, or ignorant, of that in which they are often so deeply concerned. It is under this peat that shell marl occurs, as it is also the evidence of former lakes, or pools; and a geological eye will generally detect the places of these, however long solidified, as the agriculturist may now learn to do the same: and had the origin of peat been as well understood as it has been largely discussed, this valuable manure would not be the rare and accidental discovery which it now is.

The next division is that of Forest peat, including submerged wood; while if some writers have assigned this origin to all peat, no other answer than the present history is necessary. And in every case of this nature, the far larger portion is produced by plants subsequent to the fall of the forest, so as to be, in reality, a marsh peat; as, further, this is continually forming in moist woods, from the fallen leaves

and branches, and from growing plants; so that this species is always of a mixed nature. The ultimate fall of the trees produces the purely forest peat, giving the peculiar character to the whole; while it depends on other circumstances, whether such timber shall preserve the character of submerged wood: the chief of these being, a growth of peat subsequent to its fall, so rapid as to protect it from the action of air and water. In these cases, oak is often so well preserved, being sometimes also dyed black by bog iron, as to be applicable to the purposes of joinery; and if the roots are often entire when the trunks have decayed, it is merely because they have been most deeply situated. This fact, with others, has given rise to the notion that peat possessed some mysterious antiseptic powers; as these have been sought in tannin, which is casual and rare, and in some acid, which does not exist. The case is analogous to that of piles, and the solution the same. I need scarcely remark, that forest peat must vary in character, according to the nature of the trees, the degree of decomposition, and the proportion of marsh peat; while, when most perfect, it is flaky, or schistose, retaining, more or less distinctly, the traces of the original wood.

If I have not distinguished Submerged wood from forest peat, being essentially the same, the geological position of the former should prevent observers from confounding it with the lignites, as they have done: while, being of very different ages, they also differ in their chemical qualities. In our own country, tracts of submerged wood occur in Orkney, Anglesea, Mann, Lincolnshire, and elsewhere. The latter are remarkable for their extent and situation, while similar beds occur in Holland: and near Modena, according to Ramazzini, there are two noted deposits separated by

a bed of clay containing marine remains. If it has often been remarked, as if there was here also some mystery, that the trees of such a deposit lie in one direction, this is but the consequence of the prevailing winds to which the fall of any such forest must be attributed. In Lincolnshire, however, many of the trunks are in their natural position: and I need only further add, that if observers have described such deposits as if containing only trunks, branches, and roots, they always comprise the usual marsh peat which attends that of forests. And if such wood often retains for a long time its original vegetable character, so, in other cases, it becomes more or less converted into peat, acquiring a mixed chemical one; while, as I shall hereafter show, a longer continuance of the same action of water converts it into lignite.

Maritime peat appears to have been almost forgotten by the writers on this subject; but it is formed under the sea, by the Zostera marina abundantly, while it is produced in another manner by the plants of salt marshes. It is abundant, under the former cause, where the æstuary of a considerable river is a deep fiord; the extension of the shallow shores gradually also producing a salt marsh, when the last species follows. When purely submarine, it is often an important formation: the banks of Zostera detaining sand, so as to produce bars, and ultimately islands; thus affecting the navigation of shallow seas, and obstructing harbours; or, reversely useful, by consolidating shifting bars and banks. Thus also it often commences the foundation of maritime plains; as, in Scotland, it is rapidly uniting the islands of Barra and Vatersa.

In these cases, it acts as the subaquatic lacustral plants do in lakes, by detaining earth; while the semimaritime plants which follow, produce a marsh, and

ultimately a meadow, just as the ordinary marsh plants do in the other situations. And as fresh water marl is produced in the one case, so do beds of maritime shells and fragments alternate with the peat in the other; as alternations of mere sand or mud are equally obvious of explanation. It is in Holland alone, as far as I know, that some of the deeper peat is derived from Fuci, such as the serratus and nodosus; and the Zostera oceanica has been found in Somersetshire with submerged wood.

I have adopted the word Transported for the last variety of peat; and, when consolidated, it is the most perfect, since it consists of the powder of this substance, deposited by water, in cavities. Hence it is frequent in mountainous situations, in small patches: but I am not aware of any large tract in Britain, except that produced by the celebrated eruption of the Solway Moss; though it is said to be common in many parts of Europe.

On the Generation of Peat.

It is easy to trace the progress from the vegetable to peat, in the sections made for procuring fuel; consisting in a regular gradation from the organic body, through the half decomposed vegetable matter, to that solid mass in which all those traces have disappeared. This is easily done in the peat of lakes and marshes at least; though, in all cases, the change consists in a progressive decomposition, of which the last result is a powder; being, under the drainage of declivities or peculiar exposure, the heath soil of gardeners, as, under water, it is the black mud of bogs. And this, being dried, is an elastic substance, resembling wood in all but texture; forming the best fuel, but being the least fit for cultivation: while the various modifications depend on the generating plants, the degree of decompo-

sition, and that of the drainage, as connected with time, position, and climate. If it is easy to trace the whole process in the Sphagnum palustre, it is not difficult in all the other plants: the former being a sort of immortal existence, through its offsets, succeeding to the death of the lower portions, while the other plants add annually to the heap of decomposing matter as they extend upwards; perennial under new productions, or reproduced, as successive annuals, from seeds. Hence the increase of peat is constant, as long as there is a living surface; yet under some variations highly interesting in rural economy.

That of mountain peat, for example, is steady; because its texture allows it to receive the seeds of the same plants, though the living surface should be removed. Yet its growth is stopped by changing the vegetation; as it is by calcareous manures, by burning, by the pasturage of sheep, and by the growth of larch; the three former comprising the usual processes by which brown mountain land becomes green pasture. The formation of marsh peat is checked by its own growth upwards, gradually excluding water; though it may continue to increase, as mountain peat, under somewhat different plants: as an entirely new vegetation, whether natural, or artificially produced, causes it to terminate for ever in a grassy meadow. It is obvious that the generation of forest peat ends after the fall of the wood which is to form it, though it may continue to grow as marsh peat: while that of the sea and of lakes terminates with the exclusion of the water; though, in each case, the process may continue by the growth of marsh peat, terrestrial or marine. To the formation of transported peat, there is no limit but the cessation of that flow of water by which it was deposited.

It is now easy to account for the naked and termi-

nated peat-bogs of mountainous countries. With the exception of mountain peat, every spot once denuded remains naked, and therefore ceases to increase; while it is refractory to vegetation in proportion to its compactness. Thus do the excavations made for fuel remain for ever at a stand, except when, by retaining water, they give rise to a new vegetation through aquatic plants. And thence the practice, in rural economy, of replacing the vegetating surface after excavating for fuel; under which the increase proceeds as before.

Though I formerly alluded to the time necessary for producing a given thickness of peat, the variations are too great to allow of any general deductions, notwithstanding the idle speculations of De Luc on this subject. On the continent, it is said that a depth of seven feet was produced in thirty years; while the often quoted cases of Drumlanrig, Loch Broom, and Chat Moss prove nothing, since the depths are not recorded. It must indeed be plain, that no instance is a rule for another; since the fall of a forest may produce a thick stratum in a short time, as the production in a fast shoaling lake and a luxuriant marsh must differ from that on a dry soil or in a deep water, as a small pit may fill rapidly, and as a transported bog may form a deep deposit in a single day. It is the same as regards climate: since he who should make a Dutch marsh the rule for a Highland mountain, would produce conclusions as valuable as De Luc or Rennie. Instead therefore of quoting cases, I shall suggest the necessity of careful observation on the nature and origin of any tract, before attempting to reason on its age; as I have sketched the preceding history, far too briefly indeed for any other purposes than those of geology, that I might clear the subject from all preceding mystery and misrepresentation. Yet I must suggest, in

addition, that such conclusions will often be more safely derived from the nature of the peat than its bulk, or thickness; the progress towards bituminization always denoting antiquity, while its alternations with alluvial strata will afford other obvious grounds of judgment.

Considered as a soil, peat differs according to the sources of its production; and thus it may be powdery, or semifluid, or spongy, or fibrous and semi-organic, or compact; as, under these different conditions, its specific gravity varies, so as sometimes to exceed that of water, when it produces the best fuel. It is not within my limits to enquire into the treatment and application of peat soils; but it is always useful to correct error, and to reduce volumes to words, by a recurrence to general principles. In a loose and powdery state, peat is already fitted for agriculture; while, being soil and manure both, it is eternal. When compact, it will neither receive a seed nor transmit a root; while, if wet, it is not merely averse to other vegetation than that which produced it, but will neither admit the tread of animals nor the operations of the plough. Nothing therefore can well be more simple than the theory of its treatment; which is, to drain the wet and pulverize the dry. It is no very abstruse matter to determine how these things may be done; while they who have produced their respective volumes on this subject, in Scotland, might have saved much writing had they enquired how nature assists, in England and Holland, in rendering peat a fertile soil; though they should also have recollected that there are two elements in the calculation, the sun and the rains, which they cannot command. Respecting mixtures and manures, of which more than enough has also been written, there is nothing

which is not obvious, or does not belong to the general principles of agriculture.

On the Chemical Nature of Peat, Lignite, and Coal.

Having given the reasons for uniting what could not have been separated without inconvenience, I must commence with the first of these kindred substances. The brown colour of mountain streams proves that peat contains an ingredient soluble in water, though small in quantity; as it is formed also, only in the incipient stage of the process. Perfect peat communicates no stain to cold water, and but a slight one at the boiling heat. Having already questioned the imaginary antiseptic power of peat water, I may remark that the small quantity of tannin occasionally present is the produce of Tormentilla or other plants, and that when an acid does exist, it is the acetic, generated during the formation of the hydrocarbonaceous compound, just as it is in the process of roasting, or incipient carbonization. And if animal bodies have sometimes been preserved in peat bogs, it has not been enquired whether the soft parts were not converted into adipocire, as the effect of water merely; as is probably the fact.

On this soluble matter I must premise, that when vegetable substances are exposed to heat, the carbon and hydrogen, with some portion of the oxygen, and also of the azote, produce new combinations, under different proportions, which are partially soluble in water; as is familiar in the case of sugar, malt, and coffee; while acetic acid, holding some of this compound in solution, is also generated. Now the action of water is similar, though tedious: yet rapid in such a case as that of manure, compared to vegetables producing peat: while here also there are produced a soluble and an insoluble compound; the latter being

very conspicuous in the water of dunghills, but much less so in the case of peat, where the dilution of the acid impedes this effect, as the quantity of water renders it more difficult of discovery. In both cases, the aspect of the soluble compound is similar, when dried, as are the chemical properties; but as I cannot here discuss the whole subject, I must limit myself to that which is produced from peat. This is sometimes found interspersed with that substance, giving it a pitchy appearance, and having thus been mistaken for bitumen; while being sometimes deposited in distinct masses, it has also been taken for asphaltum, which it resembles in its colour, lustre, and fracture. Yet, though originally dissolved, it has ceased to be soluble, even in boiling water; not only in this its indurated state, but in that soft condition also in which it is first found. Of its other properties, I shall only add, that it is not soluble in ether, alcohol, or naphtha, the last circumstance strongly marking its difference from asphaltum, and that it is heavier than water, and not electric. On distillation it produces the same substances as ordinary peat, viz. tar and acetic acid, while charcoal remains behind; thus proving the presence of oxygen, though the minute quantity in my possession did not allow me to ascertain the azote, as in peat. With alcohol, ether, and the fixed alkalies, the results are the same as with peat: while both form a saponaceous compound with the latter, as bistre, so analagous to this in its nature, does.

It will immediately be seen that this substance includes the basis of the whole enquiry as it regards peat: being, if I may so term it, the essence, or pure chemical representative of that substance. But as my object is to explain the progress from the vegetable to coal, I must next enquire of the relation of peat to

the bituminous lignites, as forming the intermediate transition. It is true that the peculiar qualities of peat have been attributed to bituminization ; but I shall prove that there is a complete distinction : nor have I ever seen a specimen containing bitumen, except under a very high antiquity, or from casual impregnation. The limit between peat and bituminized wood is indeed evanescent ; yet it is necessary to mark the boundary wherever it is possible, that the latter may be ranked with the lignites. I must, however, here be brief; but I have formerly treated this subject very fully in the Geological Transactions and elsewhere.

Chemistry does not yet possess any means of directly analyzing the hydrocarbonaceous compounds ; and I have therefore adopted the antient process of "destructive distillation," under some care and refinement. In the usual rude manner of proceeding, the results were worthless ; as the products consisted partly of new compounds, and partly of the chemical elements present : with more attention, the former alone are obtained ; when, by repeating similar processes, the elements themselves can be procured, or inferred with sufficient accuracy for the objects in view. Thus the progress of the change can be traced, from the vegetable, through peat to lignite, and finally to coal.

If vegetable matter be thus treated, the volatile products are acetic acid, oil and tar; charcoal remaining behind ; but as the real nature of tar had never been understood, I must remark that naval tar is a compound of this substance and turpentine, as pitch is an analogous one, combining bistre and resin. By further distillation, the vegetable tar becomes thick ; until acquiring the consistence and aspect of asphaltum, it is the bistre of artists. In this process, according to the heat, more tar is procured, or else, more acid and volatile

oil are given over; while, the bistre itself giving out the same products, the final remains are charcoal, as before; though, in the last stage, carburetted hydrogen alone is procured, as, by still urging the first charcoal, the produce is hydrogen, with the usual well-known change in that substance. The chemical reader will understand the nature and causes of what I cannot here afford to detail. In the usual coarse manner of operating, just as in the wasteful practice respecting coal gas, two distillations are going on together; and thus the produce is a mixture of hydrocarburetted gas and carbonic oxyde, while the volatile oil is itself converted into gas, so as to escape notice, as it had formerly escaped discovery. It may indeed be obtained by redistilling the tar, but is then dark and thick; approximating more nearly to that, as a greater heat is required to separate it, and thus maintaining that exact relation to naphtha which pervades the whole of these compounds as compared to the bitumens. When obtained by a low heat, it is as colourless and volatile as pure naphtha; under which name I perceive it is now sold for use, as it might have been ever since the distant period at which I published this "discovery;" then also pointing out the use of this "essence of smoke" as a substiute for smoking in the curing of meat. Though of little moment for my present purpose, I ought also to add, that a small quantity of ammonia is also obtained; combined, of course, with the acetic acid.

I need not be more chemically minute respecting an analysis which I only want, here, as a foundation for the enquiry respecting the progress from peat to coal. Sufficient accuracy for this end is attainable, by attending, generally, to the proportions of these several substances in the two cases of peat and the bituminous lignites. Commencing therefore with peat,

as the first remove from the vegetable, the results are similar, but the proportions of the products different; becoming most sensible as the peat departs furthest from the plant, and being very decided in that which is perfect and inorganic. The proportions of the acid and the volatile oil are diminished, and there is a larger produce of the pitch, or bistre: so that, neglecting the azote, as here of no moment, the change from the vegetable matter to peat consists chiefly in a diminution of the hydrogen and oxygen, compared to the carbon.

Recurring now to the action of water on the vegetable compound, the resemblance of its effects to those of the incipient action of heat, will be sensible even to those who are but slenderly acquainted with chemistry. Under heat, the hydrocarbonaceous compound becomes partially soluble in water, as in the case of coffee, while acetic acid is also generated, aiding in this solution as far as it is not volatilized. In the case of water, converting the vegetable into peat, the same compound is produced; while the differences are easily explained, as the chemical production ceases at an early stage of the process, and the ulterior changes are merely mechanical. The acid also is carried off by the water as fast as it is formed; aiding, however, in producing that solution which forms the brown water; while, remaining united to it under the other process, it increases its solubility. And this matter, collected by natural deposition, is the pitchy substance already described as the "essence" of peat. It is pure peat, in a chemical sense; while, whatever slender and unessential differences it may present, as is true of every one of these varying and indeterminate compounds, it is analogous to, if not identical with, the bistre produced by the action of fire. Thus the actions of fire and of

water on the vegetable compound are similar: in the case of the two bistres, from water and from fire, they are identical: and whatever other differences there are, they are explained by the imperfection of the process in peat, and its perfection in the case of fire; since, by the latter, the whole process is completed in an instant, as, in the other it may occupy centuries. Thus, except in the case of solution, the hydrocarbonaceous compound forming peat could not be identical with the produce of fire from the vegetable substance: but all that is essential to the present question remains. This is all that I can afford on this subject; but here all comparison between these two agents ceases. Fire has never yet produced that further change, either on vegetable matter or peat, which follows the prolonged action of water, namely, bituminization. This is the generation of the woody lignites, as the preliminary to the formation of coal: and I must now therefore proceed to the subject of chief interest under this question.

The first needful enquiry, here as before, consists in the chemical differences between the bitumens and these results of vegetable decomposition; as the assignment of a test for the commencement of bituminization is also necessary. And the distinctions in question will be rendered most apparent by comparing the several substances where they most resemble each other.

The decided varieties of Bitumen are, asphaltum, petroleum, and naphtha; the others being mixtures or modifications of these: and they are severally analogous to the bistre, the tar, and the volatile oil of wood or peat, while they all undergo similar changes from the action of air and from heat. Thus the asphaltum and the bistre produce petroleum and tar, by distillation; as, by the same process, petroleum is se-

parated into asphaltum and naphtha, and tar into bistre and the oil of wood; both the solid compounds equally terminating in charcoal, and each oil becoming a hydrocarburetted gas. And, under exposure to air, the transitions, in both sets, are similarly uninterrupted, if under differences of rapidity in the changes.

With this general analogy, however, there are important differences, most striking in the fluid varieties. To pass over the other chemical relations, the oil of wood does not unite with naphtha: and hence the vegetable tar and the bistre are not soluble in it, just as asphaltum and petroleum will not dissolve in the oil of wood. Thus does naphtha offer a convenient test of the progress of bituminization, for geological purposes. Where that is but commenced, as in some antient peats, the products of distillation will not indicate the change, though they may suffice in the lignites; while, by means of naphtha, the mixed produce, in oil or tar, can be sufficiently analyzed for all the ends of geology. The smell, indeed, is so different in the two oils, as to be test enough for general use: while their mixture, as produced from a peat in the incipient stage of bituminization, explains the peculiar odour of certain peats when burning.

Thus is it easy to trace the progress of this, from recent peat, in which it has not yet commenced, through the more antient submerged woods, brown coal, and surturbrand, down to jet; the most perfectly bituminized of the organic vegetable substances, still however showing those traces of the tar or oil of wood which disappear only in coal. Of antient peat in which bituminization has commenced, the papyri of Herculaneum offer an interesting example, since they contain matter soluble in naphtha: while they, who, as chemists, ought to have known better, have

attributed to fire what has been the effect of water. This is the only agent capable of producing that change: and these papyri are, simply, peat, passing towards lignite.

The relative nature of the bituminous and the corresponding compounds, like that of the change from peat to lignite, can be inferred by the same species of examination. In both cases, carbon and hydrogen form the bulk; but the carbon seems to bear a greater proportion in the former, as they also produce more ammonia and less acid; indicating differences which I need not explain to chemists, as I need not here pursue the chemical enquiry. Yet I must note, that I here use the term lignite, only for the organic or truly mineralogical ones: the geological lignites being, chemically, as well as mineralogically, coal.

Having already shown that peat is a compound slightly removed from simple vegetable matter, and intermediate between that and lignite, I have thus also further cleared the way for the geological question which concerns these. But the change to lignite is gradual; producing varieties in which the two compounds that form the essence of peat, and bitumen, are mixed in different proportions. The same action of water also, which converts the vegetable into peat, can produce the further change to bitumen, as it does in the earth; though the time required is very considerable, since that occurs only under a very high antiquity in this substance. And as the most perfect lignites are also the most antient, the degree of bituminization in any more modern one being also gradually less, down to the confines of peat, so do I infer that the prolonged action of water has effected the ultimate change, as it has produced all the inferior ones, or can change and has changed peat into perfect lignite.

This inference is indeed drawn from geological facts, or from a comparison of the nature and antiquity of these substances, implying more or less of exposure to water. We cannot demonstrate this by experiment, for want of the necessary element, time; yet there are chemical facts and analogies to support it. As the chief difference between the bitumens and the analogous compounds, consists in the superior proportion of oxygen in the latter, the process of bituminization is, in some measure at least, one of deoxydation: while the actual power of water to effect this, is proved by the fact, that peat contains less oxygen than recent vegetable matter. Thus also does the conversion of turpentine into resin by exposure to air, imply deoxydation; though, with other analogous changes, always attributed to the reverse. And the same effects, from the same causes, are produced on the different liquid bitumens and on the analogous compounds from vegetable distillation; though, in all these cases, new balances of the hydrogen and carbon are also formed. There is also a further analogous case in the production of adipocire; demonstrating the power of water to produce changes as great as that in question, and sufficiently similar.

But as it is my duty to examine falsehood as well as truth, I must here note the hypothesis of some imaginary chemists, that bitumen is produced from vegetable matter by heat, and that coal therefore is a result of fusion; since a true theory of coal is here the ultimate object. The adduced experiments are sufficiently discreditable; as the produce of the treatment of wood in close vessels, so far from being coal, is not even bituminous: while only great carelessness could have produced that bistre which was mistaken for asphaltum. Yet in the lignites or coals of the trap rocks,

possibly have been first produced by heat, ...nverted into coal, or asphaltum, through ...e the vegetable resins are thus bituminized, ...en loss of form; partially in the retinasphal... ...ovey and Highgate, and perfectly in the case ...r: the former, especially, illustrating the gra... ...tion of water in the cases of peat and lignite. ...ting that the chemical nature of this process, of all these substances, is now at length intelli..., I may proceed to what remains respecting coal; ...ng that term, as I have the word lignite, in its mi...nlogical sense. If Kirwan, equal, on this subject, ... his chemistry and his geology, determined that coal was a compound of bitumen and charcoal, I need not point out the puerility of his experiments, and scarcely indeed the ignorance of his phraseology. Charcoal itself is not a simple substance, but bitumen is as compound a one as coal; every one of these inflammables consisting of the same elements, if in different proportions: so that we may even conceive a series beginning with carbon and ending in hydrogen, while the actual one ranges from naphtha to anthracite. Though chemistry must take more accurate views, knowing that other elements enter into the bitumens, this general one is sufficient for the present purpose.

The different kinds of coal form a series, graduating from the bitumens, and commencing, as nearly as is well possible, where asphaltum stops. Cannel coal, the most inflammable and volatile, stands first; followed by the less bituminous "parrot" coal of Scotland, successively by the "fat coals," through the several varieties that are distinguished by their different dispositions to "cake," and then by the dry ones, such as Welsh culm and Kilkenny coal; while the series terminates in anthracite, approaching to charcoal, yet

containing less hydrogen, and therefore verging nearer to plumbago, the nearest substance to metallic carbon that we know. Nature herself almost gives us this series, including plumbago, from one original substance, under the presence of trap: as I long ago showed that this last must be an oxyde of carbon, from the facts which attend its production from cast iron. And it must now be plain, that the varieties in this series depend on the varying proportions of hydrogen and carbon, just as in that from naphtha to asphaltum; rendering the chemical theory of the constitution of coal, no less than of these substances, perfectly consistent and simple. The other differences between the two sets are chiefly of a mechanical nature, belonging to the mineral, not the chemical characters; and if, especially, asphaltum differs from the nearest coal, it is because it has been produced from a liquid bitumen; having thus a relation to coal, similar to that which the aqueous bistre has to ordinary peat. In what manner Nature has produced these varieties, it is not so easy to conjecture, though the basis is plain; yet, it is certain that a resinous plant, such as a fir for example, would produce a fatter coal than an oak, because the resin itself is converted into bitumen.

On the geological connexions of Peat, Lignite, & Coal.

Using the term in its mineral sense, lignite presents no difficulty; being derived from submerged wood or forest peat. I have shown that all the deposits of this substance are of a far higher antiquity than any peat; and thus the degrees of bituminization are accounted for, even up to brown coal and jet, though there may be other causes also, still unknown to us. And if there are lignites produced from any other kind of peat, I am not aware that they have yet been discovered.

If the contrast between peat and coal is far greater, the resemblances are too striking to leave a doubt of the origin of the latter from beds of that substance. I have shown that all the geological circumstances are similar or identical, in both; the alluvial beds of the one corresponding to the rocky strata of the other, as do the deposits of organic substances; while the insulated condition of each class is also a striking point of resemblance. The mechanical structures of peat and of coal often also present sufficient analogies: the resemblance of forest peat and the latter being often absolute in all but the mineral character; as, in both, do similar organic remains occur, and in a similar manner, while, in both also, they are sometimes wanting. The chemical facts already discussed, trace the last stage from the first, through the intermediate lignites, as, through this, coal has probably passed; so that it only remains to account for that dense mechanical form and texture, of a schistose character, by which this substance differs, not merely from forest peat, but from jet, the most perfect lignite, as the nearest in its chemical nature to coal, or, if thought necessary, by which the most fusible coal differs from asphaltum.

I have just explained why, in this last substance, the charcoal is in a state of minute division, while that of any coal must be continuous, as having been derived directly from an organic structure. In the other case, if jet, or lignite, retains the organic form, while coal has acquired a mineral schistose texture, it remains to enquire what that cause may have been. If jet be fused in close vessels, its mineral character becomes undistinguishable from that of coal, as its chemical one but slightly differs. Had the theory which produced coal from the action of heat on wood, known this, it would have at least appeared better founded: but it

would not have been the more true. There is no proof that the coal strata have been subjected to the requisite heat, as there are many reasons for believing the reverse, except in the vicinity of trap; the results in that case forming also an unanswerable objection. An igneous theory requires a pressure sufficient to prevent such an escape of the volatile matters as would leave charcoal remaining; yet having escaped, even in the vicinity of trap, so that the coal is often charred, this should have been a general occurrence. When it is said that the bituminous shales have been thus produced, it is forgotten that these are rare, when they ought to be universal; while they are easily explained through mixtures of organic matter, perhaps sometimes of bitumen, with clay. But it is a fatal objection, that vegetable fragments could not have been preserved, either in the coal or the associated shales, under the presumed fusion, even of peat or lignite; as these persons also should have remembered that all traces of organization were destroyed, even in their own wretched experiments. Yet if any one will still maintain, with Breislak, that the proper coal series has been exposed to great heat, this will scarcely be asserted of the oolithe and the green sand, in which the lignites are perfect coal. Yet I am indifferent though this were proved: since, were the coal even fused, like the jet in my experiment, it was already coal chemically, as this was bituminous, and from the same cause. Yet there should then be no shells in the limestones of that series; since I have proved that they are obliterated by such a heat.

There remains therefore no agent but pressure, united to the action of water; equivalent, surely, to the effects, when it has converted clay into shale, and calcareous mud into limestone. I formerly showed how

geologists have overlooked the power of this great agent, as the vulgar do: and there is not much more difference, thus far, between coal and compact peat, than between a tree and the board of jet produced by pressure. It is also as easy to see how the minute texture of ordinary peat should admit of its conversion to coal in this manner, as that clay should thus become shale.

It is an act of kindness not to examine Dr. Hutton's theory, which produces coal from smoke deposited beneath the sea. As to the geological position of any coal, it is a question of relative antiquity: like all strata, it once existed on the surface, in its germs: and the prime enquiry, in every case, ought to be, respecting what must once have been, from what is. There are lignite coals, it is possible, as there are organic lignites, which have been produced from such transported masses of wood as those of the Mississipi; but the greater number are of another origin. And did geologists attend more accurately to what is daily passing before their eyes, (a task more difficult than inventing hypotheses,) their science would possess much fewer of the mysteries against which I have so often contended throughout this work. The far larger number of all the coal deposits are now lying where their progenitor plants grew: and their positions respecting the rocky strata are as easily explained as those of the conchiferous limestones. And, reasoning thus, I trust that I have rendered the theory of Coal, both chemically and geologically, as perfect as any branch of Geological theory, and more perfect than many.

CHAP. XLV.

On the Alluvial Deposits.

THE surface of the earth is almost every where covered by loose materials derived from the rocks of which it is formed. The general actions connected with some of these have been already examined; but the deposits themselves require a further notice, as do the circumstances under which some of them are produced. And if all alluvia had formerly been considered as deposited on the surface, the remarks on Italy have shown that there are some which have been elevated together with the subjacent rocks. I must therefore divide them into submarine and terrestrial. The former are necessarily antient. The terrestrial may be distinguished into antient and modern; being the result of the unknown actions, while termed, by some, diluvium: an appellation better suppressed, because connected with an hypothesis already rejected. The modern are the result of the disintegration of rocks *in situ,* of the descent of the summits of hills along their declivities, and of the action of existing waters; of rivers or of the sea.

Submarine Alluvia.

Respecting these, I can add little to what was said in the sixteenth chapter, having no further facts: it remains for Geologists to investigate the districts where they may be expected, and thus to extend our knowledge on this important subject. Yet since the rocks in general were elevated from the bottom of the sea, it is more than probable that many of the older alluvia belong to this species. It is difficult to account for the rounding of fragments by temporary

currents, even under the rational views formerly given : but if the strata brought up the loose submarine deposits when they were elevated, this difficulty vanishes ; while the currents then produced will also account for the transportation of the materials, and further explain the difficulty of pointing out instances so demonstrable as those of Italy.

Thus, we may probably explain, under a principle never yet imagined by geologists, yet resting on demonstrated facts, many, if not all of those troublesome cases of alluvia, transported or otherwise, which have given rise to such absurd theories as those of De Luc and others : while it is also plain that the "debacles" of Saussure demand what he did not know, to become an intelligible theory of much that he had vainly attempted to explain. The boulders are ready : it is only to distribute them : and the power to distribute is in the same place. Even such granite boulders as those of Isla thus cease to be a difficulty, if we consider them to be the remains of the submarine alluvia, brought up together with the island : while it is easy to see, universally, how every lighter material must have been removed by that power of rain which carries off the solid surface itself. I should further add, that such alluvia may become ultimately associated with those of the present ocean which I have separated from the tertiary formations : or rather, become the same thing, under similar causes; since I have shown that many of these, as they are now situated, depend on elevations of the land, although gradual ones. This is one of those frequent cases where systems of classification become imperfect ; but if geologists will consent that both cases shall be ranked as alluvial, the needful distinction becomes easily made. And if the organic substances, jet and

amber, supposed to belong to alluvial soils, appertain to the marine deposits, these considerations may often explain their present positions, as their beds will be the very alluvia in question.

Alluvia of unknown Origin.

The next of the antient alluvia are the inferior of the terrestrial ones, and they may also be considered as of a general nature, to distinguish them from those which are the produce of visible actions. Of the probable causes of antient currents I have treated, in the twenty-second chapter; and that such currents did attend the elevations of the strata, seems fully proved by the nature and positions of conglomerate rocks. I have shown that the strata of schist and sandstone must have been the produce of slow actions, while the conglomerates were the result of tumultuary ones. These, it is remarkable, occur wherever an entire change of parallelism takes place, or, at those points which mark extensive revolutions of the earth. They were probably formed from the tumultuary alluvia of the waters put into motion by those changes; and they indicate, by analogy, that similar actions must have produced the corresponding alluvia on our globe, which are as yet unconsolidated. I need not suggest more minutely the explanations which might be offered of their various appearances and modifications; but I have formerly pointed out one cause, in early and peculiar rains, sufficient to produce great effects, and perhaps some of those which cause our present difficulties. That they are often confused by modern actions and modern alluvia, I shall shortly indicate; and hence the frequent, or the almost insuperable difficulty of distinguishing them, with the perpetual mistakes under which the recent ones have been re-

ferred to them, especially by the supporters of a well-known hypothesis.

The judgment must be determined by their positions, their extent, and the nature of the materials; and, above all, negatively, by the absence of all other possible causes. If the original directions of any currents which might have deposited them could be ascertained, there would be little comparative difficulty; but as that is hopeless, from the necessary intricacy of such currents, this must be attempted in another manner. Every torrent, be its extent what it may, must have deposited its solid contents under one of the following circumstances. Wherever it met with an obstruction, they must have subsided on the face of it; yet not extensively, unless it was wide and great. Where it formed an eddy or a bifurcation, or under any other circumstances of retardation, producing a lee place, there also we should expect alluvial deposits, extensive in proportion to the extent of the slack water. And thus, any other kind of retardation, arising from its approaching cessation, the attainment of an equilibrium, or the forms of the land, must have caused the water to deposit its contents. Hence, though we cannot, from the current, prove the deposit, we may infer the direction of the former from the places of the alluvia; a judgment aided by comparing the materials with the distant rocks whence it is supposed to have flowed. Thus, if the granite blocks on the Righi and the Rossberg belong to the Alps, while the fragments of those mountains must, on the contrary, be sought in the Canton of Zürich, we infer the former existence of a current from the south-east.

In all these attempts, if difficulties arise from the intermixture of modern alluvia, and from subsequent disturbances, others are found in the changes which

the forms of the land itself have undergone. Thus, if the preceding case be of this nature, the blocks in question must have traversed, not only many small vallies, but that of the Rhone, now 3,000 feet below their places. To produce further illustrations would be to repeat facts familiar to geologists: and after all the attempts to explain particular cases, this continues to be one of our difficulties; whatever causes we may assign for the changes in the forms of the land.

The preceding suggestion respecting submarine alluvia offers a more probable solution, at least, than the floating of ice, the excavation of such vallies as that of the Rhone by its own river, or other conjectural causes; among which, however, the decomposition of conglomerates, *in situ*, will be considered hereafter.

On these general principles also, which regulate the deposition of solids from water in motion, we may sometimes infer an antient deposit, merely from the places which it occupies; adding, of course, the negative proof from the absence of other causes. I do not perceive that this reasoning has been applied as it ought, to the obscure alluvia of our own country, or of Europe at large; while such an origin has often been ignorantly assigned to cases proceeding from the effects of decomposition, and of the descent of materials along declivities; not unfrequently also to the accumulation in the seats of antient lakes. All these are cases which require attention, but for which no rules can be given, beyond those which may be derived from the present and former remarks.

As the rounded form of the materials is rather inimical than favourable to the opinion that this has been produced by temporary currents, since we know that this process requires a long time, it can not be held to prove an antient alluvium from such a cause,

while it is universal in the alluvia of rivers. But when the exact rocks with which they exclusively correspond, can be discovered at a distance, if also these are of a rare and singular nature, and, more particularly when their place coincides with what might, for other reasons, be imagined the direction of such a current, still taking care to exclude all possible rivers, the evidence is commonly as good as can be expected. If such "diluvian" deposits have been named in England, I must refer the reader, not to the statements, but to the proofs adduced: in Scotland, they are extremely difficult to prove; while if I think that I have seen them anywhere, it is, possibly, in the central Highlands, where they might have rested, during an equally possible flow of water over the exterior country. If I were asked for another probable or possible example, it is the northern extremity of the Isle of Mann; yet even this may be a deposit from tide currents, under changes of level: and I name this striking instance here, as a caution respecting similar cases.

But let this never be forgotten, neglected as it seems to have been, that no alluvia from such a cause can ever be stratified, or separated into layers of fine and coarse materials, in any manner: while if that had been remembered, or known, we should have had fewer reports of "diluvian" alluvia. And I am bound to add, that the adduced instances of "diluvian" deposits have not carried conviction to many, that, among the most active observers of the continent, the belief in *diluvia* is far from prevalent, and that there are some who deny the occurrence of any other extensive alluvia than those which occupy vallies as the probable produce of running waters or powerful casual and local torrents. The evidence supposed to be derived from organic interred remains has been exa-

mined in a former chapter, under the question of transportation; and I shall only further remark, that when the presence of shells, when deposits of shells lying in their natural positions under subsidence, and when even such deposits, of the most tender shells, uninjured, have been pointed out as instances or proofs of a "diluvian" deposit, it is in vain to make an answer to any one who can, at the same time believe that these deluges, or this Deluge, demolished mountains, transported granite blocks, and rounded the materials of such alluvia.

Alluvia of Disintegration.

Of the modern alluvia, the simplest are those which arise from the disintegration of rocks; lying in the places where they were produced. The general fact and its causes were formerly described; and they may commonly be recognized by the following appearances.

In examining the rocks below them, we find those, at first, merely fissured, and then divided into fragments, which, gradually diminishing in size, are at length intermixed with clay and sand, or, finally, converted into those snbstances. In some instances, the disintegration is more perfect; but the fragments are angular, or, if otherwise, bear marks, not of attrition, but of decomposition. Gneiss, argillaceous schist, limestones, and sandstones, present examples; and the consequences are easily traced in the resulting soils. It is one of the great processes in nature for producing these. In the unstratified rocks, and sometimes also in gneiss, decomposition is more common than disintegration; and hence the produce is more frequently clay, or clay and gravel, than in the stratified. But, how deep and extensive the former may be, can be conjectured, when I have traced them, in

Scotland, on the red sandstone and on the coal strata, to depths ranging from thirty to fifty feet, and covering miles of country. That these have been the preparatory steps to many of the obscure denudations, I cannot doubt: since it is impossible that any current of mere water, or even of water charged with fragments, could demolish mountains; above all, within that very brief time which must be allowed to "The Deluge." Woodward's theory, suspending the laws of cohesion, could alone produce such an effect: but we smile at Woodward, and forget that we are believing in him under another shape.

If generally easy to assign, the alluvia of disintegration are sometimes rendered doubtful by the disappearance of the parent rock, or obscured by the intermixture of transported materials. Thus, beds of gravel, or sand, or clay, are often found under circumstances which render their origin uncertain; while they have occasionally been ranked with transported, and even with "diluvian" deposits. But the discriminating marks can often be traced, in veins or other appearances, remaining, in the nature of the neighbouring unchanged strata, or in the absence of indications of transportation: while, in the unstratified rocks, where the original mass has disappeared, their origin is proved by finding a dark soil incumbent on a sandstone which could not have produced it, as I noticed in treating of denudations. The induction is complete, when nodules, fragments, or agates are found in such alluvia.

This disintegration, in conglomerate rocks, has often given rise to the belief in transported or diluvian alluvia, as just remarked: and thus may be explained many of the blocks which have been invested with a mysterious origin: as well as the flints or gravel derived

from lost strata. Thus have I at length unexpectedly explained the trap boulders, bearing every appearance of transportation, which are so abundant and troublesome in Scotland; having found them, with all the polish which friction could give, imbedded in the unmoved clay derived from the original rock. It is easy also to see, how further deceptions may arise in this case: as a river may thus transport the rolled stones of a conglomerate, themselves transported, ages before, and rounded by far other rivers. Such alluvia occur in the Alps, and also in Scotland; while, probably, many examples in England, otherwise explained, will admit of the same reasoning.

Alluvia of Descent.

The necessity of entirely revising the alluvia, hitherto confounded by geologists, to the utter confusion of the science and the production of the most extraordinary hypotheses, has caused me to give this name to those which are produced by a combination of gravity, aided by rain, with the ordinary disintegration of the summits of mountains. These occur on all declivities, and consist of clay and sand with fragments, often of great size, which, if generally angular, are sometimes slightly rounded, from partial attrition or decomposition. Their real origin is indicated by their position, by tracing the progress of the operation, and by the nature of the substances. Their depths vary according to innumerable circumstances, and they often descend so far as to occupy the vallies beneath. Thus, it is not exclusively by the action of rivers, that the mountains are lowered, as I formerly remarked; less perceptible agents give their aid, in an effectual, if in a silent manner.

In rocky mountains with considerable acclivities, the protrusion of the naked summits, with the visible fall

of fragments and the accumulations of these below, are sufficient evidences of these alluvia and of their cause; but, in other cases, it must be sought in other indications less obvious. Such is that permanence of trap veins noticed in treating of denudations; while as these appearances occur on very gentle declivities, as in Cumbray and Isla, or almost on level ground, as near Comrie, here is a demonstrated cause, of even transportation, which geology has overlooked. That even "boulders" may have been gradually moved, in this manner, to great distances from the parent rock, is abundantly obvious. And I may here say, once for all, that whatever volumes may have been bestowed on these "travelled blocks," there is no reason for separating them from the several classes of alluvia to which they belong.

Alluvia of Rivers.

A due attention to the two preceding classes of alluvia, will disengage the question of "diluvian" deposits from much of the obscurity in which it has been involved; but the greater confusion on this subject has arisen from those deposits by rivers, to which this term is more strictly applicable.

Though the conclusions respecting the alluvia of rivers must be modified by recollecting that these may have sometimes transported the materials of more antient deposits, so as to have simply transferred what they found, without destroying the rocks, it is seldom easy to separate the two sources, nor is it often necessary. I must here therefore consider the alluvia of rivers as being their own produce; having thus provided against an error, which is, in the present discussion, of no moment; since that which has been placed by a river, is, in reality, its alluvium. And as these are

fonnd accompanying the present or former courses of streams, they occupy vallies, or plains, or the seats or borders of lakes, or maritime æstuaries.

It is almost to repeat former remarks, to say that the mountain torrent commences in a rocky channel, generally becoming wider and deeper in its progress, that at a certain stage, this bed displays fragments, and, at length, consists of rounded pebbles and gravel. The declivity, and consequent velocity, diminishing, the deposit becomes finer, and, as it reaches the plain, the rocks disappear, even from the banks, which finally become unequal, alternately presenting deep sections and flat shores. The course of the stream here becomes variable and shifting; while the plain displays hillocks and terraces of loose materials, the remains of the banks which it has successively deserted. A section through the plain, discovers a considerable, but variable depth of the same materials which form its surface; but during the whole of this progress, the deposited materials become gradually finer, as the declivity diminishes in the actual stream or in its immediate vicinity. The advance of the larger fragments ceases when that has been much reduced; and that of the materials which friction takes from them, if still exposed to water, must therefore occupy years: the heavier permanent alluvia remain only because the stream has deserted them. Hence the different characters of these alluvia at different points of a stream, at differents parts of a plain, and at different depths; since, at the same point, under a greater rapidity, consequent on a greater declivity, to be computed from the depth, the materials must differ. And hence, in the first case, engineers have computed the necessary bulk of these at several points, relatively to the slope, or to the velocity of the water. I must however remark, that even large masses are some-

times deposited by the casual force of torrents or inundations, independently of these more regular results; a circumstance aided by the diminished weight of stones when in water, and often exciting wonder in those who are not aware of this necessary fact. If these are other irregularities, they may be attributed to lateral streams or temporary floods. This regular procedure can not however be traced in all rivers; so, that, while some terminate in the sea during their full vigour and flow, others present only the appearances which belong to the last stage.

With such and other variations on which I need not enlarge, the sections of a river alluvium present marks of stratification, not always horizontal, by which, as I have already said, they may be distinguished from antient deposits, even where no river now flows. Yet, as many rivers have originally met the sea or a lake, at points far higher than their present junctions, their alluvia are often modified by actions that might easily be overlooked. They sometimes also enclose strata of peat or vegetable soil, formed during a period of repose, in a plain or on the margins of a lake, and afterwards overwhelmed by inundation. Hence also we account for the presence of organic remains, and, sometimes, even of marine ones, far removed from the present sea. It is superfluous to say that the nature of the fragments must correspond with those of the rocks in which their streams arise or through which their early progress lies, except in the case of the passage of these through an antient alluvium.

The superficial features of river alluvia are often modified by the passage of streams, or by occasional inundations; and hence many intricate appearances, which have caused them to be referred to "diluvian" sources. Such are, terraces, hillocks, and other irregularities;

the solution of which is generally easy, by attending to the varying courses of the waters, and to the different streams which may have acted on them. The most remarkable however of these terraces, are those found in the wider vallies and plains; the deserted banks, and thus the records of the former places of the river: their height marking its former elevations, and their positions the lateral changes of place which it underwent in sinking. To enumerate the varieties in these endless appearances, and to trace minutely the mechanical causes, easy as it may be, would lead to details fit only for that work on this specific subject, which, having written, I here abridge.

Thus also would it be tedious, and, I trust, superfluous, to note what occurs in these alluvia where they meet the sea or lakes: though, in the former case, it must be remembered, that being a point perpetually carried forwards by their deposition, these appearances are often found far inland. At the actual point of deposition, the effects vary according to the forms of the shore; and by attending to these and to the effects of the waves, we can explain the various produce, in banks, spits, and islands, the filling of bays, the conversion of marine inlets into fresh water lakes, or the reverse, on which I formerly said all that seemed necessary. In the latter, the stratification of the alluvia is even more remarkable than in the other deposits of rivers, as might be expected: while I need not note the other obvious distinctions in these cases, since they are easily conjectured from many preceding remarks: though it is easy to see how any lake, forming marl beds, or shales, or travertino, while deep, will accumulate only alluvia at its final term; thus explaining the appearances in the antient lacustral deposits, even as it regards the presence of terrestrial organic fossils. I

need only add, that the existence of marl beds always, and of peat and organic remains generally, will demonstrate the former places of water at points whence it has long been excluded; that the shoaling of a lake is comparatively accelerated, and also modified, by the vegetation on the margins, often producing peat bogs; and that other modifications result from the shoaling sometimes proceeding at many points, in consequence of the entrance of lateral streams.

On Maritime Alluvia.

I have shown that these are generally produced by a concurrence of the action of the sea with that of rivers; nor can the former often produce extensive deposits of this nature, derived from any other source. The chief exception is in the fragments detached from cliffs or rocky shores, which, having been rolled or pulverized by the waves, are rejected on declivities where they are enabled to rest. On the spits and banks produced by the ordinary course of currents or tides, or by gales of wind, I have formerly treated: as this is the point at which the alluvia of rivers become confounded with the present. In all such cases, the nature of the alluvia is complicated: but however the land may have been modified, the progress and the causes may be ascertained, by finding marine remains beneath; or by the alternation of terrestrial and marine deposits. The common linear exposed shore requires no remarks; yet Bute and Arran offer striking examples of entire flat belts at the foot of the high lands, produced by the action of the sea on alluvia of descent. When this occurs in bays, considerable tracts of useful land are sometimes generated. I must yet remark, that the action of the sea in these cases, is, like that of rivers, twofold; and that its ten-

dency is to remove, at certain times or places, what it had before deposited; from variations in the forms of the land itself, the nature and effects of which I formerly discussed.

I may rank the transference of sand with the maritime alluvia; though there is one conspicuous case of a different nature. Being generated under the water from quartz or shells, and deposited at high water-mark, it is dispersed by the winds; often overwhelming large tracts, and forming such sand hills as those of Holland, the Baltic, Vera Cruz, and so forth. In favourable circumstances, it may also generate land; and thus Tirey appears to have been almost entirely produced in this manner, from reefs of bare rock. In such cases, it is consolidated by vegetation, as its progress may be arrested by the well-known plants created for this especial end. But it is not always injurious; as, when calcareous and widely dispersed, it operates as a manure to rude pastures, and thus extends a valuable vegetation.

Though the origin of quartz sand is thus obvious and simple, another view has been sought, in an imaginary precipitation from solutions in water: an argument which has been supported by the defined crystals of the sand of Neuilly. But the reasoning formerly adduced against the production of rocks from solution is here equally applicable; while this case is easily explained by the occurrence of crystallized quartz in some granites, and probably in many other rocks. It is a common case of decomposition: while, in every other instance, the forms of the sand are too imperfect to have been thus produced.

The following cases belong strictly to the alluvia of disintegration; while the foregoing hypothesis has been especially applied to these deposits. I have for-

merly shown how the decomposition of sandstones produces deep-seated sand beds; and it is equally plain that superficial ones must generate sands subject to transportation, as the quadersandstein does; while such is the probable origin of many well-known sands in the north of Europe. But, while the most noted of these are the sandy deserts of Africa and Asia, I have already shown that they have been derived from the red marl: while it is easy to understand how the gradual disintegration of the surface must continue to produce that, of which the effects have been described in such terrific colouring. If the presence of salt has given rise to the unfounded opinion that such deserts had been lately covered by the ocean, or were its deserted bed, I have already answered this; as I have shown that the shells of these deserts are not marine. The elevation of the great Steppe of Naryn in Tartary, is itself sufficient evidence that the present sea was not the parent of these salt sands. It is nevertheless possible that a sand of this nature might belong to the elevated submarine alluvia: as it might thus be called, and perhaps may have been, a "tertiary formation." I do not believe that any geologist will hereafter think thus of the deserts in question, at least; while, in any doubtful similar case, attention will be required in discriminating the clays and sands arising from such local disintegration. It is from their apparently eternal reproduction that the spreading of these sands is explained; that which the winds remove being replaced by the destruction of fresh rock. Hence the well-known extension of those which are daily burying still deeper the architectural remains of Egypt; while, if I dare not indulge in this interesting subject, we may thus explain much that appears obscure in antient history. Palmyra was not always the arid desert that it

now is. I shall only further say, that this subject has been often treated by writers, and especially by De Luc, in a very tedious and useless manner.

Of Soils.

Such is the mixed origin of the agricultural surface, that it could not rigidly have been classed with any of the preceding divisions. It is only where the soil is untransported, that it can be dependent on the nature of the rocks beneath: and such, in general, are the soils of low countries, and of lands which do not conduct rivers; though, even in these, there is that insensibly transported soil, which is generated by the gradual flow of water along the surface. Were it not for this, the effect of the rains would soon render bare and sterile the steeper and more elevated lands: while in this we must admire that provision, simple as beautiful, by which this evil is averted; one of those circles of destruction and reproduction which prevail throughout nature: the same act also which removes the soil, giving access to the causes which disintegrate the subjacent rock.

Where a single rock is the parent of the soil, the effect is easily foreseen; where more have interfered, the results are proportionably complicated: while, further, as already remarked, it is sometimes utterly unrelated to the subjacent rocks, where trap has disappeared; as calcareous soils often also exist where the parent stratum has vanished. In simpler cases, we can trace the clay, the loam, the gravel, or the sand, of a soil, to the original rocks; and thus does a knowledge of these sometimes become useful to the agriculturist. He may thus even learn to foresee the eventual loss of that which cannot be replaced, or, from the source of eternal supply, pronounce on that

which will probably be as durable. But more information than the knowledge of soils can give, has too often been expected from it: since the accessory circumstances of drainage, retentiveness, climate, &c. too commonly defeat the prognostics of the Analyst.

The alluvia of rivers form the soils of those plains and deltas so noted for their fertility. It is the slow motion of water which has rendered Egypt, Bengal, Lombardy, and a thousand similar tracts, the seats of inexhaustible fertility. Thus also are stored up, in lands now far remote from their rivers, those soils which these deposited under former positions; and it is here chiefly that we may witness the important consequences arising from the destruction of the solid earth. In nature's hands, the barren and useless summit of the mountain generates an empire: the eternal harvests of Italy are produced from the naked Alps. But though the basis of all soils consists in the common earths, the most important ingredient is the produce of vegetable decomposition: and thus, through the marvellous circle of nature's chemistry, the elements of organized bodies, dissipated by the winds or dispersed through the earth, return to their original forms.

Alluvial Rocks.

I must still notice a class of rocks which could not well have found a place before, and which, from their daily production, are best ranked here. If their geological importance is not very great, they offer some valuable evidence, to which I have resorted more than once.

I have shown that the consolidation of sand and fragments can be effected by carbonat of lime, by iron, and by solutions of silica: but it is doubtful if the last cause operates to any extent at present. I know

of no modern rock thus generated: nor has any extensive mass of rock, produced by rust, been described, though partial conglomerates of this nature, occur in gravel beds, on sea shores, and in places where ferruginous springs flow through loose materials; as I have also found conglomerate veins produced in this manner in Scotland.

The only alluvial rocks which demand notice for their own intrinsic interest, are those produced by carbonat of lime. Of these, there are two distinct cases; both of them interesting, from the extent of the produce, the errors to which they may give rise, and the illustrations which they afford respecting the antient strata.

If the important strata formed from fragments of coral, enabling these islands to surmount the highest rise of the ocean, demand no further notice, the similar productions so extensively generated in the West Indian islands, and, in the Bahamas and Bermuda most conspicuously, produce modern oolithes resembling those of the antient strata. If the want of observations does not enable us to decide on the present value or effects of these productions, we cannot doubt that extensive strata are thus forming in these regions; while under the processes of elevation already suggested, whether gradual or sudden, it is easy to imagine the importance of the results, in the production of a supramarine and calcareous territory. Of the analogous rocks produced on sea shores in Europe, those of Messina offer an example well known from their extent and their œconomical uses.

The other case, remaining for notice, is the production of calcareous rocks, at the present day, and also in the times of the alluvial deposits, from solutions of carbonat of lime alone. If the formation of stalac-

tical rocks is unimportant in a geological view, I have formerly shown the interest attached to it when involving the bones of animals. The production of travertino, chemically the same, is much more important, from its extent, and for other reasons. If it occurs at Matlock and elsewhere, it is best known in Italy, where it is the present produce of lakes and rivers, as it has been from a period beyond record. Its use in the antient and in the modern buildings of Rome is familiar; as is the great depth of this deposit in many places. I have already shown how the formation of this rock has produced obscurities respecting the loose alluvia of Italy and the volcanic tufos; while it is easy also to see, how, by the casual superposition of alluvia, or of the matters of volcanoes, on antient travertinos, the latter might be mistaken for an ordinary calcareous stratum; and how, in particular, confusion has thus arisen respecting organic remains. And if, as is probable, it occurs in many other calcareous countries, while hitherto overlooked, as it had long been in Hungary and in the vicinity of the Black sea, it will be for geologists to enquire, whether they have not sometimes confounded it with their "tertiary formations:" while, if now forming in other lakes as well as those of Italy, it may hereafter be mistaken for lacustral deposits of a far higher antiquity. Such a deposit is indeed, essentially, but the same thing; and it thus unites the phenomena of the present with those of more distant days.

I have allotted no chapter to the volcanic rocks; as I have nothing important to say of them beyond that which was said under volcanoes. With this one, the history of the materials of the earth is terminated.

CHAP. XLVI.

On Theories of the Earth.

I HAVE reserved to this place the following slender but necessary account of geological theories; as the reader will now be a better judge, and as I need not also, now, bestow a minute examination on them, or labour to refute what stands self-refuted. But I do not intend a history of geology or of geologists: I must leave to others what would be more easy to write than to read, and try to gratify a rational curiosity on easier terms. And if a record of error demands criticism, so have many preceding allusions rendered that necessary: while, the more distinctly the wrong is made visible, in the clearer light will the right appear.

But, as many of these differ in their very design, I must premise a few remarks. A "theory of the earth" may commence, with Epicurus, or with Buffon, at the creation of the globe: and where speculation has supplied the place of evidence, we need not wonder at the succession of such hypotheses. Hence the current prejudice against geological theories, among those who confound theory and hypothesis. But if it is thence argued that the pursuit is fruitless, astronomy might equally be condemned, because of its successive systems. And if also ridicule has been thrown on the very attempt, by those too whose systems best deserved it, this is but a result of the vulgar fallacy which imagines a vision and a project in the term theory. Geology would indeed have been singularly fortunate if it had not possessed its share of bad observers and bad writers: it has been notoriously and oppressively fertile in both; the refuge of him whom no other science will own; the science in which any one may assert

any thing, and, in which, to know the names of a few stones and shells, forms the Newton of his circle.

Every one ought to know what theory means: but, to construct a geological one, if facts are, as in all else, indispensible, so is it needful to possess somewhat more than what is called "experience." To see is not to observe, to observe is not to analyze and to reason: he who can do all this, may make the attempt. It is a necessary pursuit: since the laws which regulate the nature, disposition, and changes of this globe, are proper objects of scientific enquiry: while they lie within the range of observation and analogy; leaving their own visions to poetry and metaphysics. It is unavoidable also, unless a line be drawn across the path of generalization, leaving geology to be a contemptible pursuit after specimens, and a disjointed chaos of facts. And he who does not perceive its higher bearings, has forgotten that there is a Creator of the world, and that He who created governs. The theory of the earth is the conduct of the Deity respecting the habitation which He has provided for Life. Fie! that the ignorance and intolerance of a false theology should not have seen, how, in this also, we have discovered a new path to the study of His wisdom and His government.

But though a theory of the earth should prove unattainable, the attempt itself is repaid. It is not in vain that geometry has laboured to quadrate the circle, or mechanics to find the perpetual motion. He who endeavours after excellence, in physics, as in morals, will derive certain fruit, though he might have expected another produce. And, in every science, general principles are required to regulate that accumulation of facts, which is defended, to the disclaiming of all theory, by the ignorant vain, under the pride of an affected humility; not to be envied, were it even real. Impar-

tiality is not the result of this profession; excess of ardour is more than compensated by prejudices: the path of observation is not the less crooked; and, to disclaim theory, is the most pernicious of theories. But this is to waste words on a fundamental ignorance of the very nature of philosophy: in any other science, I might have spared even these remarks. In none can the very work of observation proceed without general principles; without theory. Not understood, facts are useless; but, not understood, they are not even seen. He who knows what to see, sees: and, without knowledge, the man and the quadruped, equally seeing, see to the same purpose. And if we are ever to wait for future discoveries, the result is, that we neither know what we want, nor where to seek, nor how to use what we may have obtained.

Nor can any collector of facts advance long on his principle of purity. He must soon discover some link which unites many; and from that moment he is a theorist. Under new anomalies, there must be new approximations, the impossible quantities are gradually elicited from his equation, and if he does not become what he disclaims, it is time that he should retire, since he has as much mistaken his talents as he is ignorant of philosophy. The path which he scorns will ultimately terminate in a just theory; while the purist in facts is heaping up rubbish; a mark for avoidance. If I ought not to have a reader capable of believing that theory can be opposed to facts, so do I not write for him who can confound theory with hypothesis. The spirit of system, in the latter, is a false and misleading one: in the former, it is the animating principle. The theory which is deduced from facts is ever improving under new ones: the hypothesis which stands this test long, will be more fortunate than its predecessors. If

it is the fate, even of theory, to generate prejudice, this is ever inseparable from the pursuit of truth, under human feelings. But there is a correction, in the habit of severe self-judgment; while the absence of theory offers no security against partiality; as, for the spirit of opposition, there is no corrective.

The antiquities of every science form a natural object of curiosity: but, on this, as on all else, my limits condemn me to the utmost brevity. They enable us, at least, to trace the progress of the human mind, with that slow accumulation of knowledge, by which we often imperceptibly profit; teaching us, also, that, in the same circumstances, we should have done no better. Thus we see the first steps by which observation and reasoning have felt their unsteady way, the gradual accumulation and purification of evidence, and the increased resources and severity of reason; while, in every science, there is not a step which does not afford ground for useful reflection. But the remote antiquities of geology present almost a blank. The facts are nearly nothing: and the theories are those dreams which once held the place of inductive reasoning. The classical reader may turn to Herodotus, Polybius, Strabo, Aristotle, and Pliny, for remarks on the changes of the land through the action of the sea and rivers, and on volcanoes and earthquakes; and further, to Lucretius, Seneca, and Plutarch, for theories of the latter. The facts are of little moment now; the theories of none: we know not the rocks they described; and if they knew of the presence of shells in these, their conclusions are without value or interest.

Their theories are metaphysical cosmogonies, in which "more Græcorum," words are the substitutes for things. There is no temptation to criticize them; however we may be indignant at the moderns, who have reproduced similar romances under new phrases.

But, if I should ill employ my time in the comparison, so the reader would not much admire the ingenuity or inventive talents of the collected body : though it is instructive to remark, how often rival authors have been compelled to agree, even when proceeding on different or opposing views, and how much they have borrowed under the assumption of novelty. But, through this whole sketch, I shall limit myself to a few : enough, however, to convince the reader how little he would gain from more minuteness ; while noticing more fully those only which have some peculiar claims on attention. To trace them in any chronological or other connexion, would demand more space than the subject merits or I can afford.

Cosmogonies of the Antients.

It belongs to the history of philosophy to trace this subject as it might require : but they who desire what exceeds my plan, will know where to seek, should they not be satisfied with Cudworth or Lipsius. Yet they who have sought for Greek allegories in the poetical chaos, in the moral elements of strife and discord, in Venus and Cupid, Eris and Eros, Night, Tartarus and Ether, in the Orus and the Mundane egg, would have been better employed in tracing these visions to their Oriental fountains ; unless, indeed, they now choose to believe that a phalanx of the Macedonians taught the Sanscrit language to lands which it never visited, and under an alphabet which it never knew.

Every one knows the system of Epicurus. Let his expounder be read, for he is worth reading : yet not for his philosophy : while Lucretius is not the only example of a good poet and a bad philosopher. I need not quote that which relates to the present subject : it is nearly nothing.

But though I had not premised it, I choose to place

here, a theory, for which the name of La Place or of La Grange will equally suffice; as I shall also make some use of it hereafter. If it is not borrowed from Epicurus, neither did he foresee that a view so resembling his own in all but its bad metaphysics, would be produced at a future period, under the evidence of facts and general laws; that atoms might concur to form an earth, yet under the direction of the Deity, even though we cannot prove that they have done so. It is a singular coincidence between an unfounded guess, and what is, at least, a theory. Arguing from the apparently gradual condensation of comets, it is conceived that the earth was, originally, a gaseous planet, while all else follows in order, under the laws of heat and chemistry; the first subsequent condition being that of a fluid globe.

I need scarcely say that the system of Aristotle is not thus atheistical: while, in accounting for the arrangement of the earth, there is some attempt at a theory founded on facts, though adapted to his metaphysical views of the adolescence and decrepitude of the globe. Where the necessary eternity of the earth is deduced from the length of time required to produce these changes, we are reminded of some modern speculations, formerly examined; as we thus discover their want of claims to novelty. As far as the doctrine of the Stoics differs, in assigning understanding to matter, I shall again refer to the originals, those who may delight in Greek logomachies: while they will at least find eloquence to supply the want of philosophy; a consolation wanting, to balance equal defects in the Werners and the Kirwans. If Plato, similarly borrowing from India, considers the universe as eternally co-existent with the Divine mind, yet as created by it, we cannot much reverence his metaphysical accuracy. But Plato's reputation was not to be

destroyed by such objections; while it carried this cosmogony down to after ages, as I need not say; having written enough on those who have produced "tant de phrases et si peu de choses." Yet in distinguishing those, who, though considering matter eternal, believe the present form of the universe to be comparatively recent, we approximate to some of the modern theories of the earth.

The Oriental cosmogonies are interesting, chiefly, as giving the genealogy of the former. That of the Egyptians, claiming Thoth as its Buffon, is imperfect: but he who desires more than I can give, will find it in Eusebius. And if its fundamental part, the action of the Orus on a Chaos, is familiar, I need not also say where a parallel doctrine is found, under a very different authority; nor that Plutarch and Eusebius disagree respecting it. Geologists will be more interested in knowing, that Egypt considered the earth as subject to certain periods of revolution, and that it was to be destroyed and renewed by fire and water: whence the Ecpyroses and Cataclysmi, and the Great Year of Greece. And if, according to Zeno, the fires concealed within the earth will at length set it in flames, while the inferior divinities are absorbed into the Supreme Spirit, who, after a certain repose, will produce a better world, we trace the oriental doctrines which he had derived from his parentage. I may refer to Seneca and Lucan: but thus are the inferior Gods, Brachma, Vishnu, and Sivh, to return to the Unspeakable intelligence, while the Calpas of the same school are the revolutions in question. Here also we discover the origin of the Millenarian hypothesis; while, if the curious reader desires to amuse himself with the opposing opinions of Justin Martyr and St. Jerom, so may he learn at how many periods it has been revived,

ever as new as it is now, to those who know not "quam multa renovantur quæ jam cecidere." And as if human invention was really never to be new, here also do we find the parentage of that more modern system which is at length a theory under evidence; though he who may vainly seek geological knowledge in Sanconiatho, will search to as little purpose the records of Hindustan.

If the Chaldean cosmosgony deserves notice here, it is chiefly from having furnished that of our Northern ancestors. The Chaos, of water and darkness alone, contained certain monstrous animals, which were slain by Bel, together with the goddess Omorca, who, being divided, produced the earth and the heavens: while, as man was formed from her head, thence, says Berosus, his intellectual powers. In the Voluspa, Alfader created all things; before which, all was a continuous abyss. Heaven and earth were no where: yet Niflheim and Muspelsheim, the hell of frost and storms, and the luminous world, had been prepared. Hence shall issue Surtur, the genius of darkness, with his flaming sword, vanquish the Gods, and consume the universe. The reader can turn to the Edda for the contest of the sons of Bore with the giant Ymir, the result imitating the fate of Omorca, as for much more: but the conflagration is succeeded by a new earth, fruitful without cultivation; while the death of the Gods is their absorption into the Supreme Cause. I need not again point out that origin which is amply confirmed by the history and language of the Gothic race.

On certain modern Cosmogonies.

If, under this division, there are some rivals of the former inventions, so are there some, partially supported by facts. I have no intention to examine this

mass of borrowed, or inane, or visionary matter: and if I have selected what seemed, for some reason, to deserve it most, the reader will scarcely complain that I have not thus occupied more of his time: the present will amply justify that neglect. If I pay no regard to their claims to priority, it is that the chronology of folly or error is not worth settling.

Whether he knew it or not, the original globe of La Marck was that of Chaldea, but the "monsters" were monads, or organic particles; some destined to form vegetables, and others animals. The animal monads, producing, first, microscopic infusoria, gradually acquired higher organizations, through their own desires, and became, at length, the present races; as the vegetable ones, similarly, became the plants that we see. Thus preceding the solid earth, marine shells constructed lime, and vegetables clay, instigated by the want of a soil; while these two earths produced the others; but, whether by so desiring, is not said. And thus did animals and vegetables create the earth from a sphere of salt water. I have done more than justice, since I have not told all, to him whom his age esteemed a great Naturalist. He might have been so: in empty shells. If this be Epicurism, and not disease or imbecility, he should have asked himself who created the salt water and the monads. But when did human folly become a warning to its like? The past year has seen dust moving in fluids, and the "philosophers" of to-day have rejoiced in new monads, uninformed, alas, of their antiquity. The system of De Maillet, copied by Darwin, is scarcely worth distinguishing, though admitting an original land: but it requires little discernment in modern Epicurism, to perceive that purpose, in some, which the folly of others has, perhaps unsuspectingly, imitated. Such have been

the attempts, of all ages, equally, to get rid of their imagined enemy, the Deity himself, and such the blindness which does not see that He is still behind all, the irremoveable; the Necessary, the Eternal, The Cause.

If I need not assign the relative merits of Kepler and Patrin, suffice it that the Earth is a living animal. Vital fluids circulate, minerals are produced by assimilation, the mountains are lungs, the schists are glands, secretion causes volcanoes, and even chemistry is an animal power. Patrin at least was a geologist: conchologists or geologists, "haud multum distant." I need not however tell the scholar that this "vitality" of the celestial bodies has not the merit of novelty; and all can see that the sympathies of molecules are the "understanding" of the Stoics.

Bertrand finds the earth to be a hollow sphere including a moveable magnet. The approach of a comet alters the centre of gravity, and thus the earth is inundated: whence the several irruptions and retreats of the sea. But Mr. Marschall has discovered that it was formed from meteoric stones, which, arriving from other spheres, brought with them the organic bodies of those worlds; whence the lost species of our own must ever be sought in vain, without, at least, the powers of Micromegas. It is not surprising that geology has been a subject of ridicule.

Theories of Burnet, Whiston, Woodward, and others.

Though the "Sacred theory of the earth" is an hypothesis, Burnet is not without arguments drawn from facts; while we must not forget how little was known in 1681. Yet has he furnished valuable hints to modern system makers; while, in his eloquence and the grandeur of his views, he has had no rival,

leading also to comparisons little flattering to his successors. We need not wonder that he acquired an extended reputation, as his work became the incitement to rival and successive theories. Rejecting the antient philosophy, he maintains that as the earth was created so shall it be destroyed: while one of his arguments has been used by a recent writer, almost in his very words. I shall refer to the passage where he remarks, that if the earth had existed from eternity, it must have acquired a very different appearance, from the waste of the mountains and the displacement of the sea; since Burnet must be in every hand. I do not make a work, little indebted to the labours of others, a repository of quotations.

The remarks on the condensation of the original chaos, serve, as, often before, to show how little those systems which possess the reputation, have also the merit of novelty. Though with the advantages of modern knowledge, the theory of La Place is but that of Burnet. But, henceforward, he becomes extravagant: the separated atmosphere depositing a sphere of water, first, on the solid nucleus, and then an investing one of earth; the habitation of "the golden age." And the rupture of this, causing the Deluge, produces also the present distribution of sea and land. This must suffice for a writer who, nevertheless, like some green spot in the wilderness, refreshes us with a luxuriance and a variety, the more striking, from their contrast with the dreary deserts of geological theories.

The comet of Whiston, the original germ of his earth, anticipates La Place even more perfectly. As the work of creation proceeded, its contents subsided according to their specific gravities, while the nucleus still retains its heat. If he has attempted to compute the time of cooling, he has also anticipated, though

under the insufficient knowledge of his day, the views of Fourrier. But his nucleus is surrounded, first, with an "unknown dense fluid," and then with one of water; the "abyss" supporting a crust of land and seas, as the antediluvian world. The deluge is produced by the appulse of a comet, its vapour generated the "rain," the water retired into the "abyss," and the earth assumed its present form. The reader must however be told, that the heat of the original earth generated vice in the terrestrial inhabitants, while the colder aquatic ones escaped both crime and condemnation.

In spite of his practical knowledge, Woodward's system is as deficient in truth as novelty. Seeing nothing but those English strata whose influence has not yet ceased, his rocks are all deposited from fluids, horizontally, according to their specific gravities, as all contain shells. Pure ignorance is always better than falsity: the difficulties of geology have ever been produced by the Woodwards. He who must commence by sweeping, is choked by dust. I trust that my successors will have the easier task. But the Deluge, of course, forms the main hinge of his theory. An abyss is broken up by the Divine command, suspending the laws of cohesion: and so forth, as usual. Unfortunate indeed has been this random thought of Tertullian. Perverted views of an historical fact have been the eternal millstone round the neck of theorists, while the patient observer could form no plan, of which this was not the foundation; as, even now, they who should know better, adopt a load which they cannot carry, hoping, often, to gain favour, or something better; hoping, at least, to escape that which has been hurled to crush conscientiousness and truth. But why should we ridicule him who dissolves the insolu-

ble, suspends the law of cohesion, and finds that vertical strata are horizontal; why smile at him who, thus armed, can accomplish any thing? Theories, yet lauded, have done as much: while followers are fiery in defence of that, under one name, which they condemn under another. The plagiarist ought not at least to abuse his original.

Scheutzer is the mere echo of Burnet and Woodward: and this bare notice will suffice for many more, who have similarly wrought for some fame in this field; as the system of Burnet will serve for that of Descartes. Yet there are writers, of different dates, to whom geology is indebted for somewhat better. I cannot here settle the contending claims of Rouelle, Steno, Targioni, and Lehman: but in these we trace the first attempts to account for the present distribution of the surface, by earthquakes, deluges, and other transitory events. And if the first hint of the powers of antient currents did not originate with Steno, it is, at least, not the suggestion of those who have drawn so largely on it. If also Lehman has been called the father of modern geology, he has been over-rated; when he must forfeit his claims to originality, and when even his division, founded on a false criterion, corresponds, in name only, with the facts. The name of Whitehurst is enough: and if geology stands indebted to Lister, Catcott, Mills, Michell, Vallisneri, Arduino, Raspe, and others, they belong to the history of the science, not to the present sketch of theories.

Systems of Saussure, Werner, De Luc, and Kirwan.

Coinciding in general views, these names are the chief supporters of aquatic or "Neptunian" theories; as they also bring us down to our own times. The reader will soon judge of the comparative merits of

those who abounded in materials and those who possessed none; while if he knows what a theory means, he will think an ingenious hypothesis more entertaining than a clumsy one.

If Saussure, however, is rather a disclaimer of theory than a professed theorist, he shows considerable vacillations of opinion, with marks of unwilling conviction against a favourite system. The land was originally covered by the sea, but the strata were broken by some interior revolution, forming abysses and elevations; while the waters, rushing into the former, excavated vallies and deposited alluvia. Thus, the strata, formed by precipitation, were elevated; while, in another place, he imagines them to have been disposed as they now are, by crystallization. Promising to state, in future, the result of twelve more years of thought and labour, "he dies and makes no sign." His opportunities and labours are known: so is his reputation: let he who can now value him, judge of his merits. I will not criticise him: but the justice due to others, demands that he should be weighed. It is plain, however, that he once adopted the essential part of a "Plutonic" system: that term which, with its opponent, has made the bitterest of enemies, even of those who did not understand the subjects in dispute. The evil spirit must ever find vent in something.

If Werner's system first appeared about 1787, its subsequent modifications prevent us from knowing with whom its several portions now rest. While his audiences diffused it with the blind zeal of religious sectaries, his lectures became the endless treatises of all who sought the fame of geological authorship. But, to entertain an opinion is not to form one: and hence the student, influenced by the weight of numbers, should recollect that but one voice speaks through

all these organs. If, therefore, the leader should be charged with the faults of his followers, it is the sect which is the object of examination: while it is an idle office to settle the contending claims to ignorance.

In an originally fluid earth, the materials of all minerals were dissolved in water. From this, granite was first precipitated, at specific points, being followed by gneiss, and successively by the primary schists, in an "invariable order;" though it is not explained why the former is irregular, and the latter stratified. These rocks were "primitive," and anterior to the creation of animals; and they are purely chemical, as the produce of aqueous crystallization. Certain marine animals are then created: and the water having diminished in quantity, new rocks are laid bare. The precipitation, which had ceased, is now renewed; while the fragments of these rocks, and the spoils of animals, become intermixed with the new chemical precipitates, forming the "transition" class. And, because the water continued progressively to diminish, each succeeding rock appears at lower levels, granite occupying the highest place; while all rocks occur, throughout the globe, in the same order, constituting "universal formations." More land becoming dry after the transition rocks, the "floetz" rocks are formed, necessarily less inclined to the horizon, and more regular; though the reasons why, are not given, any more than for their frequent erect positions at present. And the creation of new animals accounts for the superiority of their remains in these. After this, the water rose again to deposit the trap rocks; thus once more covering, even the Andes, yet depositing them on such chosen places; as, in subsiding, it let them fall on Britain and elsewhere. But, as they lie among successive "floetz" strata, the sea rose and fell over the whole globe, as often as

it was necessary to produce the first, second, and third "floetz trap formations" in the few chosen spots where they exist. This being done, the superfluous sea vanishes for the last time, and man is created.

I have avoided a more minute account of this theory, out of respect for this philosopher; as it is unfortunately the less intelligible the more it is explained. But of all the properties of that which explains every thing in the most perfect manner, the most perfect is, that it is peculiarly and exclusively consistent with the Mosaic history, which it also proves. The reader shall judge whether those who assert, or those who believe in, this marvellous property, are most worthy of marvel. But, as Whiston says of his own, "whether it be possible, or not, such is the fact."

If it has not accounted for the "tertiary" strata, a sea so convenient might always contain the necessary rocks at the necessary places; while so moveable a substance can ascend and descend as often as is needful. The minerals of mineral veins were precipitated in the fissures, from the universal solution. Rock veins are contemporaneous with the including rocks, and formed by crystallization, as are the fragments in the conglomerates; as contortions, fractures, elevations, and so forth, are also modes of crystallization, and as are mountains and vallies; there being no subsequent process of denudation. The coal deposits were formed by an elective attraction at those points, from carbon in solution; as the vegetable fragments also tended to the same places. The induration of strata near trap, is the result of intermixture during crystallization; though the former were completed many ages before the latter were produced: and while volcanoes are purely modern, and heated by coal, pumice and obsidian are deposits from water.

This is a sufficient view of the "theory" under which all Europe became a land of philosophical geologists, for which much of Europe yet fights, and in which much of the rising aspiration is still educated. We need not wonder at the progress of geology. If future writers will pass it, together with the cosmogony of Chaldea, it still influences minds which may be startled at even the following slender criticism, which a systematic writer must not avoid, if he is to do his duty: though, to examine its loud pretences to agree with the sacred records, shall be left to those who can read a Book more often talked of than read.

As every reader must needs know the common facts of chemistry, I shall deceive no one by the admission that the whole earth is soluble in a thousand times its weight of water. It was therefore once a thousand times heavier than it is now; so that it remains for this theory to reconcile those two conditions to the laws of the solar system. Again, there being no precipitants, the rocks are formed by the abstraction of the solvent; the unintelligible "subsidence" of this system. If the water entered into abysses, then did one body contain another far larger than itself, as even thus, it would carry the dissolved rocks with it: if evaporated, it at length departed into free space, against the laws of gravity: if converted into earth, or destroyed, a new chemistry becomes necessary. But the rising and falling of the ocean are treated with as much tranquillity as if the changes of the tide were concerned; as if it could be aught but the destruction and regeneration of oceans; of a hollow sphere whose diameter is more than 8000 miles, and its thickness more than five. If, as has been said, a higher temperature might have rendered it a more active solvent, this is not Mr. Werner's theory; since his temperature permits the existence of animals.

what is impossible cannot be true, it proved, as experience has here shown, it easy to believe against the evidence of the The strata are not universal, nor every the same order, nor do they appear at successive lower levels. The antient rocks are not all chemical, nor the recent ones mechanical; while, here, the theory contradicts itself, with its crystallized conglomerates.

Nor does any chemistry explain why one rock was replaced by another, why the same compound assumed so many forms and positions, why one only was precipitated at once, why silica gave way to clay, why there are repetitions of the same rocks, why serpentine and others are so partial, and why, and whence, the ocean acquired its new materials, after having become clear for the habitation of animals. The "limestone formation suite" contradicts what it is adduced to prove; to explain the forms of strata by crystallization, is to use a term without meaning; and to call a vein contemporaneous with its including rock, is to be ignorant of the use of words. The theory of coal does not deserve a remark: and it belongs to this system, peculiarly, to have adopted the most impossible one respecting mineral veins. On volcanoes, I need only notice the overbearing confidence of the assertions; and, while grievously ignorant of organic fossils, there is not a fact respecting them which does not overturn the whole system. But more than enough: odious as is the task, such criticism is a needful branch of geological instruction: and what I have here said, I may suppress as to future similar speculations.

De Luc attempts to remedy some defects in this system, by borrowing from Saussure; whence his claims to originality are but trifling, as they are not enviable.

But, commencing with the history of the earth before the creation of the sun, he must be allowed to settle this with a science of which he had probably not heard. The continents became exposed by violent revolutions; though all the changes now attributed to terrestrial actions, took place beneath the sea. The antecontinental strata had been deposited from solution, horizontally; a mechanical deposition being impossible: and the separation of the water and air from the earth occurred from the introduction of new ingredients: all this being "perfectly conformable to chemistry," and explaining every thing. The elevation of strata being impossible, their present positions arise from subsidences, occurring under the bed of the sea, and determined by certain caverns into which the parts fell: while this "philosopher" does not see, that if elevation was impossible, because the continents must have been previously suspended over abysses, his own are in the same predicament. But if he has a contrivance in certain "party walls," I must be excused from trying to abridge what I cannot understand. In the literal, as well as the metaphysical sense, it is a chaos of words "hovering over the abyss of unideal vacancy." Nevertheless, the wind "in these caverns pent" met stones attempting to enter them, which it exploded, "like gunpowder;" whence the boulders of the Alps. Of his retreats and inundations, I formerly said all that was necessary.

Kirwan has as little claim to originality: his demands to notice are founded on his high tone, and on his asserted chemical and geological knowledge. His globe contained De Luc's caverns and Werner's solution, or "chaotic fluid;" while the crystallization of the rocks produced a "stupendous conflagration," splitting the earth, and forming the atmosphere. The

primitive mountains were crystallized from silica, and the argillaceous ones filled their intervals; when it was laid dry for the creation of animals, the water retiring into caverns, through the fissures. Fishes were created when the sea had subsided to 9000 feet; then vegetables, and afterwards land animals; the sea thus retreating though many centuries. By means of storms and volcanoes, the primitive mountains generate the secondary ones, the sea continues to retreat, and our progenitors are created.

In such a sketch, there is at least some civility: Mr. Kirwan's ambition after chemical and geological reasonings, has rendered himself a severer critic of his work than many of his readers could well be. I suppress much, for the same reason; and, of his subsidiary theories, a few must suffice. The conchiferous strata of Peru, since they exceed the limit of 8500 feet, arose from the Deluge; that eternal resource of every "geologist" who finds none in his own intellect, while, not to be appealed from, but under the fulminated penalties of all the infallible theories. But if the specific theory of this event is unintelligible in the original, some other Œdipus must abridge it. If, on rocks, all sorts of contradictory facts are collected from all sorts of authorities, it will at least offer a hint to modern system makers, should they have forgotten Mr. Pinkerton's success. And if the theory of lava fused without heat, has, in being borrowed, found borrowers equally learned in Chemistry and Geology, that of coal is so far original, that the carbon and petroleum were derived from the primitive rocks. Yet Kirwan has the abstract merit of not dealing in generalities: and had he been what his circle thought him, his book might, possibly, have been what it is not. But, Werner or Kirwan, every idol is constituted by its idolaters: and

what would philosophers, more than despots do, without their courts and their adulators? Yet were such the schools in which we were educated, as in such things were we commanded to believe, under the penalty of philosophical excommunication. And as were the teachers, so, with little exception, have been the scholars.

But all these "aqueous theories" claim exlusively to coincide with Scripture; while, not content with this assumption of exclusive orthodoxy, they have waged a spiritual warfare against their antagonists; like the Scaligers, and the Saumaises, speaking the daggers they could not wield, and thus throwing the "odium theologicum" on those of other systems: while the charge of impiety is especially urged by those whose own are most at variance with it, and the term Religion is adopted, as usual, to secure the votes of the ignorant. Every one of them demands as much time, and circumstances even more irreconcilable than the opposed ones; while, in the steps of Creation, they are utterly contradictory to the record which they wrest. It is little to have forgotten that there is such a term as Charity, and that the adjective Christian gives it some claim over those who will one day be compelled to ask for what they forgot to give: while if, with some, it is the blind zeal of hypothesis, others have considered it a profitable account for this world. From even Burnet downwards, all, all differing, claim the same; and all declare that things mutually irreconcilable, are identical with a common term of comparison: though the same charity, in another day, pronounced even Burnet's theory atheistical. But if Kirwan is among the loudest, so is he the most daring: interpreting scripture in his own way, and finally concluding, that the chances are "ten millions to one" that his own account and that

of Moses are both true, because they agree. Really, these are things which make thinking men wonder.

Enough of the "aqueous" theories: the "igneous" have been set in opposition; as if the stability of the one was to be ensured by the overthrow of the other: but he who has no strength of his own will not stand the firmer because his enemy is down. It would have been well had these terms never existed: but such things will be, when men shall become lovers of truth more than lovers of hatred.

Theories of Buffon, Lazzaro Moro, Dolomieu & others.

We have seen what the aqueous theories have proved; but there is no purely igneous one. And, hypothesis or theory, there is a chain which unites them all: while, in thus treating them, I may distribute merit where it has been overlooked, and reduce assumption to its simple rights.

The theory of Bourguet is of 1730; and though but a sketch, it has anticipated Lazzaro Moro on one important point. Buffon treats him with contempt, while apparently indebted to him for the igneous fluidity of the globe; as has been usual among geologists, concealing plagiarism by suppressing the name of the author, if not, as is more common, by abuse. But I may pass his system, together with Keill, King, and others; yet not forgetting Ray, whose opinions, whether original or borrowed, are as decisive as clear; containing those essentials of an igneous system, in which the most recent theory has made no change.

That of Leibnitz is a mere cosmogony: the earth, like the planets, having been a fixed and luminous star, extinguished under the waste of its combustible matter. This is the "separation of light:" the rocks are vitrified from fusion, quartz alone retaining its original

nature; and the water is precipitated from the air by cooling. The Protogea has therefore scarcely a novelty: as it also fails just where it is most wanted. The cosmogony of Buffon has been called an elegant romance: which is possible. But his theory is an extensive collection of facts, whence his successors have amply profited. He has been compared with a much more modern theorist: but they commence from different points, and employ their agents in reverse order: while the French philosopher also differs, in foretelling the final extinction of life, by the cooling of the globe.

The earth is a portion of the sun, transferred to its orbit by the impulse of a comet: its figure is the result of its original fluidity, and it retains a central heat. If this theory involves the whole solar system, I need not pursue what is at variance with the laws of geometry. And if, under equal mathematical knowledge, he argues for the uniform density of the earth, we must smile when he censures those who solve difficulties by adjusting the works of nature to their own imaginations. Like Leibnitz, his granite is the original vitrified matter of the globe, while sand and gravel are produced from it by fire. But the condensed vapours which form the sea, deposit certain slimy matters towards the production of strata. The diurnal motions and the tides produce subsequent changes; transporting materials to the equatorial regions, and thus generating the present forms of sea and land: while currents, still posterior, have given these primitive mountains their present linear directions and precipitous faces: generating also the Currents of many subsequent imitators. Fissures are produced by contraction; in one class of rocks from evaporation, in the other from cooling. I need not proceed: while the ignorance of Buffon's day claims

many of his suc-

the elevation of the
of Lazzaro Moro, in
e: those of Boscovich
of the earth, this has
nded as it is on Italy, he
ginally covered the whole
nimal life, that, even then,
fires which elevated the pri-
animals were produced and
also elevated with subsequent
ondary ones. These causes are
countries; and thus does the
ount for the angular positions,
r accidents of the strata, with the
nt surface. His imperfections are
sion, and would probably have been
ur present information: but this must
"Plutonic system," as it has been;
are prepared under water. Employing
d elevating force, it avoids the encum-
ll the purely aqueous theories; and if it
lly explain the production of strata, neither
pose an impossible chemistry to account for
brave, like its numerous rivals, all the laws
sciences. In its scope indeed, it is more li-
than those which have been founded on it, but
he parent of the whole: and if they have affected
pise it as "volcanic" and partial, hoping perhaps
in the credit of invention, they have but betrayed
rance, if not dishonesty; overshooting also the
k in this attempt, and committing errors in striving
deviate from that to which it has been part of my
siness to bring them back.

Omitting the speculations of Breislak, and much more, I must note the opinions of Dolomieu, who, finding certain trap rocks interposed between strata, considers them the produce of submarine volcanoes: because this also has been borrowed, essentially, but controverted, ostensibly and nominally, by a later theorist. This identification of trap with volcanic products, is an important fact; as is the eruption of lava through granite, proving that it is not the lowest rock: but, as a theorist, this geologist is essentially deficient, when he argues for "retreats" of the sea, exposing these strata; and thus, blind to what was before him, and equally departing from Lazzaro Moro, leaves unexplained the accidents of strata. And, inasmuch as he has supposed all trap exclusively submarine, he has misled Hutton, on a point not to be boasted of when borrowed, still less so when at variance with truth. It is no novelty, in him, to have supposed a central ignited fluid, the source of these traps and volcanoes: and still less is it so in Hutton. Of Faujas de St. Fond, it must suffice to say, that he, reversely, considers all trap as of terrestrial volcanic origin. Why have not these men and their followers seen, that both theories are inevitable, and that there is evidence of both? But we prefer antagonism to truth; as "the inconceivableness of something they find in one, throws men more violently into the contrary hypothesis."

The theory of Hutton is best known through the commentary of Playfair: I must make the following sketch as brief as possible; while, by commencing from the present state of the earth, it will easily be seen that it is almost a transcript of Lazzaro Moro's, with some extension, and some aid from preceding sources; yet with some important additions, united to numerous and serious errors.

The action of the elements, and the flow of water, transfer the materials of rocks to the lower lands and to the sea; and the same proceeding having occurred in former times, those alluvia were the germs of the present strata, as the existing ones are those of a subsequent earth. The antient rocky strata have therefore been produced from the waste of a former world: as their organic fossils are the evidences of former Life. The central ignited matter has protruded, as it does now in volcanoes; and, under different circumstances, has produced granite and trap, forming the unstratified rocks which have elevated the older strata, and producing their several accidents, as in the former system; while the fluid matter, filling their fissures, has generated rock veins. The consolidation of the strata is attributed to the same cause; but wherever there are differences in the action of this and of ordinary fire, it is attributed to pressure from superincumbent weight; under which the trap rocks are, falsely, said to be never cavernous; as limestones become fusible. Lastly, having conceived no other division of rocks but into primary and secondary, this theory traces but three forms of the earth, namely, that which anteceded the primary strata, that which included these alone, and the present one; though arguing for its past eternity, as it does for a future renovation, and to all eternity.

In this simple view, this system possesses an aspect which its author will soon injure, by his details. With exception of the theory of trap and volcanoes, he had borrowed well, and safely extended what he did borrow: but, with the usual ambition to erect an entire theory, though ignorant of the necessary facts and sciences, he has, in almost all else, levelled himself to the Werners; while his commentator has, unluckily for his fame, pursued the same course.

In arguing against subsidences, we trace, equally, the spirit of hypothesis and antagonism, with a want both of geological knowledge and sound reasoning. Of some structure of discontinuity, if not strictly cavernous, there is evidence in the linear directions of volcanoes; as coal, and more, are proofs of subsidences. Though gneiss, and some other primary strata, are in their present condition from heat, this mode of consolidation cannot be admitted for all strata. The theory of trap is untrue, because injudiciously rigid: while the anxiety of opposition has introduced inextricable confusion into this part of the system; under which, also, he has, by disclaiming demonstrated truths, forfeited one of his strongest supports, while maintaining a perpetual hostility against Dolomieu and Faujas de St. Fond, on the very facts by which he might have profited, but did not understand. Knowing the igneous rocks most imperfectly, he denies the existence of scoriform traps; while having recourse to a most unhappy expedient for explaining the amygdaloidal nodules. Perpetually indeed misapplying a favourite principle, even though admitting water to a large share in his operations, it is called on where neither needful to the theory nor reconcileable to the facts. Such is the unnecessary fusion of carbonat of lime, with the igneous origin of quartz, chalcedony, and silicified wood; while the theory of flints is peculiarly infelicitous and unintelligible, as is that of the septaria. But the whole theory of igneous secretion is without excuse; as it compels us to deny that this writer was the chemist he has been called. The theory of coal equals the very worst of the schemes of Werner; while it indicates that narrow spirit of hypothesis which misapplies a sound principle as often as the reverse; proving, that reasoning was, in any case, a very

doubtful cause of its successful application. If I am to do justice to my readers, I am bound to protect them from the assertion that he always proceeded on the legitimate principles of induction ; for thus, under reputed authority, is the young mind misled.

There is an equally unfortunate anxiety after the hypothesis, where the present forms of the surface are concerned: since, ever thinking of the slow action of feeble forces, he forgets that elevations must have produced inequalities, and therefore, that vallies must have existed before rivers. To deny, also, any other alluvia than those of rivers, is not only to deny palpable facts, but to overlook some necessary consequences of the very theory; while, if we can pardon the zeal of the original theorist, there is no excuse for the commentator. The system which assumes to be perfect, and whose pride will not yield, mistakes its own interests. It is beaten at the bad outposts which it is resolved to defend; while, by retiring to the citadel, it might long have defied assault.

Such is a sufficient view of this theory, and such is all the criticism which appeared due to the student in geology, while I desire to avoid what is superfluous. It is sufficient, among other things, to prove that this boasted theory is little more than an hypothesis, where it is original; yet fortunate in having borrowed a better foundation, and thus far, almost only, a theory. Yet, wishing to do justice to all, I must point out that which I believe to be original, or if not always original, important. Such is the effect of pressure, but original as to the carbonat of lime only; and such is the igneous origin of granite, since without that, there can be no Theory of the Earth : though it may still be questioned how far the hint was taken from Leibnitz and Buffon, as it is easy to believe that Lazzaro Moro would have

come to the same conclusion, had he known this rock. Let Hutton, however, have the merit; though furnished by his predecessors with all the analagous proofs, in trap and in the volcanic rocks. Yet, on the former, I must repeat, that his confusion, added to his antipathy respecting their truly, if remote, volcanic nature in many cases, must make us doubt those powers of philosophical generalization, for which he has been so lauded: an idol, like his predecessors, to his own circle. Still, the practical effect of thus reviving the forgotten Italian theory, with those improvements, was great, though even yet limited: since it found all Europe believing that the ignorance of Werner and his followers was philosophy and geology.

But it is my duty also to render justice to those antient writers, whose merits have been suppressed from design, or overlooked through ignorance: and thus must I question the praise of originality, united to splendour of views, so loudly bestowed on this "theory." These I have traced, even beyond Greece, to the Brahminical philosophy; as I have shown the remote distance, in modern times, of some others of its chief doctrines. Yet I must defend it also from certain attacks. If it has been accused of drawing unjustifiably on time, there is not a system which does not do the same, had their defenders knowledge enough to see it, or honesty enough to confess it; though its frankness will still be considered its condemnation. But, to grant this, and to admit of the eternity of the Earth, so ill argued, are different things; while I need not repeat my former objections to this speculation. As to the central heat, this system, if guilty, is not the only one, by many: but if there is not ample proof of this, I know not that geology can furnish evidence of any thing, whatever difficulties there may be in explaining its interrupted

and repeated actions. To conclude, if I have adopted neither one nor other of the rival terms of the two theories, so idly opposed, it is because this is, on one side, a censurable vanity, as, on the other, it is a pernicious flattery; being, with "eloges," and laudatory biography, an insult to truth, and a corruption of modern times. In this case, it is also an injustice to other writers; while its evil effect has been to substitute faction for philosophy, teaching men to enquire, as on a far deeper subject, not what the truth is, but who is the leader.

This sketch, serving other needful purposes, was also an indispensible preliminary to the following attempt. I might otherwise have been suspected of wishing to claim those things which, as far as my knowledge extends, I have attempted to award, in justice, to the several authors to whom they belong. It will thus be seen to whom is due the merit of that, which, be the additions and the corrections what they may, forms the basis of the following sketch; as well as the extent of that for which I must be held responsible. It will also be perceived, that even that which I have adopted, as truth, has often been, in my predecessors, but a fortunate conjecture; that much has consisted in vague generalities, often difficult of application, as unapplied by their proposers, and often disputable: and further, that with many truths, there are intermixtures of error, ignorance, and misapplications, which have vitiated their value and left them open to disputation. These blanks I have tried to fill, as I have endeavoured to furnish proofs of what was, formerly, conjecture: and thence also, in desiring to see nothing accepted but what rests on Evidence, I have attempted to distinguish its different values, under the several propositions that constitute that skeleton of a Theory.

CHAP. XLVII.

Sketch towards a Theory of the Earth.

Though a philosophical geologist will easily collect from this work, nearly all that I can myself state under the present chapter, this would be a task of difficulty to many readers, and, to the mere student, impracticable. To omit such a view, would indeed be a dereliction of duty, as it would be to disappoint reasonable expectation. It is true, that some principal portions of a theory have already been stated, and unavoidably, as general conclusions from facts detailed under this System; insomuch that a restatement of these cannot fail to involve some repetition. But while these do not stand in the order which such a sketch demands, so are there, in the preceding chapters, many subsidiary portions of a theory, of more or less moment, often also but slightly touched on, the bearings and value of which would scarcely be appretiated without the approximation and arrangement here proposed. This then it is equally my object and my duty to do: but it is not all. If there ever is to be a Theory of the Earth, it is not less needful to place our present deficiencies in a full light; that the pursuit of this science may no longer be checked, under that contentment which rests in the indolent belief that the assertions of bold ignorance are Knowledge. Let our defects be fearlessly and honestly displayed; and we shall then know what we have yet to learn; as, then also, may geologists turn their attention to the improvement of this science, to the perfection of that which is the end of all Science, a true Theory, instead of wasting their time on that which can now teach nothing new, or, still worse, in seeking and perverting facts to support hypotheses.

In both cases, in stating what I believe to be knowledge, and what seems to me ignorance, I would fain think that I have had but one object, the pursuit of truth. Whether hypotheses are the result of ignorance, or vanity, or enthusiasm, I shall not here enquire; but let the proposer of a theory, in any science, ask himself, whether, in undertaking to teach others, he has laboured to acquire a good conscience, whether he rests his claims to belief, on industry, a cool judgment, and the preference of truth to the gratification of vanity: on the love of Truth above all things. To mislead, in morals, is acknowledged wrong; to do this wilfully, is admitted criminality. Can the same conduct be innocent, far more, justifiable, in physical science? He who checks the progress of human knowledge, obstructs human improvement and human good: he is not always even an indirect source of evil.

But what is Truth? all make the same profession. Yes, there is a test by which it may be tried, and I give it in the words of one whose soundness of judgment will not easily be disputed. "How a man may know whether he be so in earnest, is worth enquiry; and I think there is one unerring mark of it, viz., the not entertaining any proposition with greater assurance than the proofs it is built on will warrant." If, throughout this work, I have taken this rule for a guide, so have I striven to follow it; and if I have kept it in view in this sketch of a Theory of the Earth, I may also add, from the same writer, that "he who by indifferency for all but truth suffers not his assent to go faster than his evidence nor beyond it, will learn to examine, and examine fairly, instead of presuming." He indeed who would declare this of himself, ought to possess the powers, the conscience, and the self-knowledge of Locke; but it were well for philosophy if all

could say, "I never write any thing but truth, and never publish any thing to others which I am not fully persuaded of myself and do not think that I understand. So that I never have need of false colours to set off the weak parts of an hypothesis, or of obscure expressions or the assistance of artificial jargon to cover an error of my system or party."

Before proceding to this Sketch, however, it is necessary to state those demonstrated facts in geology to which a reference must be frequently made or implied, as to fundamental principles; that I may command the necessary brevity. I have called them demonstrated facts, because I believe them such, notwithstanding the controversies to which many may still give rise, among the advocates of antient hypotheses; and I believe them such, on the evidences which I have given in the preceding work, as, to that I must refer; since a recapitulation of such proofs is here impracticable. It will be for the reader to judge of their value; while I trust that he, like myself, will turn a deaf ear to all that is opinion and assertion, to all that is not Evidence, and to all authority but the authority of Nature herself.

Ignited fluids, formed of certain earths, become rocks by cooling; and these, not disposed in strata, but in irregular masses and veins, are of various aspects and qualities, presenting also different crystalline and concretionary structures, which are determined, partly by the original materials, and partly by the modes and times of cooling.

From an identity of circumstances pervading volcanic rocks and the several unstratified ones, granite, porphyry, trap, and others, the same origin is inferred of all; and it is also proved that such igneous rocks have been produced extensively, at various and very distant periods.

The chemical powers of air and water change the

aspect of these rocks; as the latter penetrates and unites with them; depositing also aqueous minerals in their cavities, when these are present. The further action of these powers decomposes and disintegrates them; while, under each form, and, in the latter, under fragments of various sizes, they become moved by gravity and the flow of water, forming alluvia, on the surface of the earth, and beneath the waters: the latter constituting strata, which according to various circumstances, differ, and form successions, in parallel order.

All this, which occurs now, has also occurred formerly; and thus too, as such strata are now consolidated into rocks, so have they been similarly consolidated in former times. They are now consolidated by solutions of earths in water, by pressure, and by heat; and thus have they been consolidated at distant periods. Lastly, such consolidated strata, or rocks, have been subjected to the same chemical and mechanical actions as the igneous rocks; and they have, in the same manner, furnished materials for alluvial strata, separately, or in combination with those.

Wherever heat has demonstrably acted on strata consolidated by water and pressure, or, possibly, by a small degree of heat, their chemical and mineralogical characters are changed: and the peculiar differences between the more antient and the more recent strata, are therefore attributed to this cause, as operating through the igneous rocks: the more antient stratum being the lowest, and the more recent the highest, in geological position. And under the extreme effect of such heat, in peculiar circumstances, such a stratum may become an unstratified rock; because under a similar condition to a stratum fused in a volcano. Whence also, the near resemblance in the mineral characters of certain strata and some unstratified rocks.

The solid spoils of animals, chiefly marine, consti-

tute limestones at present, and have produced them, at distant and different periods, in immense masses; nor, for those of present times, is there any other origin than animal chemistry; except, that limestones must be reproduced from limestones, as sandstones are from sandstones: though it is still inferred that such was the first origin of the whole; which diminish in quantity as we retrocede in the order of the strata, or the age of the globe. These strata thus furnish that criterion for the number of animals at any period of the Earth, which is, more obviously but less sufficiently, proved by their actual preservation in such strata.

The solid parts of vegetables now produce peat, which passes, under greater antiquity, to lignite, and lastly to coal: for which, as in the former case, no other origin can be assigned: while, in a similar way, the actual fragments of plants preserved in these strata, further prove that such is their origin. It is less safely inferred, however, that there is no other origin for carbon than vegetable chemistry.

The principal strata were formed under the sea, and at different periods of repose; being also originally in a horizontal position, or nearly so. And any set of strata, maintaining a parallel order, has been formed in one such period. But the first strata must have been produced from the waste of igneous rocks; since this is a necessary inference from the very nature of stratification. Thus does a stratum containing a fragment of a former one, prove an anterior set belonging to a previous period; as that fragment would prove one still anterior, should it contain the materials of a stratified rock, under whatever form. Whence is established the former existence of sets of strata and periods of repose in the earth, of which we have no other evidence.

The formation and protrusion of igneous rocks have

disturbed any previous set or sets of strata: and, at as many periods as disturbances of sets of strata can be proved, at so many have there been distinct formations of igneous rocks, or protrusions of ignited fluids. These are Revolutions, of, or on, the surface of the Globe, inferred to be general or partial, according to the extent of the demonstrable effects. Their relative dates are inferred by those of the strata on which they have acted: while every later one must have caused a fresh disturbance in all that was anterior, under each division of rocks.

The disturbance is proved, chiefly, by a change of parallelism in sets of strata: adding, in most cases, appearances in them, indicating the tumultuary motion of large fragments; and, in recent ones, the absence of limestones and the remains of animals: as thus does a new parallelism indicate a new period of repose. And, under these disturbances, strata are changed from their original positions, elevated, bent, fractured, and chemically affected, while also penetrated by veins of the igneous rocks; as these themselves are, when more antient, by veins of the more recent ones.

The final past effects of all this are; to have caused frequent changes in the places of the land as it relates to the sea, with varying changes in its elevation; to have gradually multiplied the number and variety of the rocks, as also to have augmented their general quantity, compared to that of the fluid portion of the globe; to have destroyed or diminished, at several periods, previous organic creations; and to have accumulated their spoils in limestones, and those of vegetables in coal. And the final present ones are; to be extending the habitable surface, in various ways, and to be preparing strata, beneath the waters and on the dry land, which are apparently destined to a similar fate, at a future period, and with similar results.

And such a sketch of the only general facts yet ascertained, resting therefore on Evidence, while excluding what is at present unknown or conjectural, comprises the fundamental materials of all geological knowledge at present, as it also forms the basis for a Theory of the Earth, such as that can now be inferred. It is the Machinery of Nature in the regulation of the Globe, as far as we can yet discern: or it includes the Secondary causes through which The Deity has proceeded, and is proceeding, in the arrangement and government of that Earth which has already constituted the habitation of different orders of animals, which, in comparatively recent times, has recieved Man, among others, and which is further destined to an office which we cannot conjecture, however analogous we must suppose it to that which is present and is past. I may now therefore proceed.

Passing at once from the Act of Creation, and from the planetary arrangement of what is called Matter, under a term which is admissible, however, but as an abstract and mathematical one, the first condition of the Earth which has been inferred, is that of a Gaseous sphere: while it is my business to state, that the only evidence for this is derived from the analogy of comets, itself rather more inferential than proved, as far as the study of these bodies has hitherto proceeded. But it must also be said, as corroborative of such an inference, that the laws of the radiation of heat, and those of chemical combination, do permit the needful inference, that such a sphere might, or must, finally become a fluid; or at least a fluid globe surrounded by an atmosphere.

This, then, is the second presumed condition; and here also the evidence increases in value: while I may notice, once for all, that I do not here intend to quote *authorities* for any of these opinions, however weighty

since it is with Evidence, and evidence alone, that I am concerned. And the evidence for such a fluid globe is found, first, in its statical figure, and, secondly, in the various geological facts, already reviewed, and founded primarily on the phenomena of volcanoes, which prove that the interior of the earth, beyond a certain depth, is at present in a fluid condition, from that heat which was once sufficient for the preceding more extensive effects.

And here terminates that which is of most difficult investigation in the Theory of the Earth, and which, by many, will still be ranked with hypotheses. The Evidence such as it is, is given: what a rational philosophy shall pronounce on it, will always deserve attention: the opinions of those who decide from prejudices, or under temper or defect of reasoning, may be neglected. Yet the limit between such evidence as this, and that of a higher order, is evanescent; so that in attempting to trace the next step, there would be room for the same remarks, were it not superfluous to repeat them.

I know of no mode in which the surface of a fluid globe could be consolidated, but by the radiation of heat; while, of the necessity of such a process I need not again speak. The immediate result of this must have been the formation of rocks on that surface; and if the interior fluid does now produce the several unstratified rocks, the first that were formed must have resembled some of these, if not all. We may, not unsafely, infer that they were granitic; perceiving that substances of this character have been produced wherever the cooling appears to have been most gradual. The first apparently solid globe was therefore a globe of granite, or of those rocks which bear the nearest crystalline analogies to it: while, if there are

now irregular movements within the earth, producing distinct expansions in different places, so should there have been such at this early period. And though we have not as yet even conjectured the causes of what is, nevertheless, a fact in evidence, we ought to admit it on the doctrine of Final Causes, or of a Directing Power; seeing that it is necessary for that disposition, or management of the Earth, the consequences of which are essential to its ends.

Thus then did this first of all solid globes become an irregular or mountainous one; while it is as easy to believe in successive eruptions of fluid matter through the portions already solidified, as in the present state of the earth; and those proceeding throughout a period of great duration, so as to produce a form capable of receiving collections of water, or an ocean. And if, respecting the precipitation of water from an atmosphere, the makers of antient hypotheses have written as vaguely as abundantly, Chemistry can now admit this, under its laws, though as yet compelled to speak in general terms.

If such is this view of the first, or truly primitive solid globe, I need not dwell on the quality of the Evidence; since, be it what it may, it is apparent. But, under the same evidence, there is now a second condition, or, from the presumed original one, a fourth, and that a Terraqueous one, or an earth analogous to the present, however differing in many essential particulars; some obvious, and others only to be conjectured.

In this terraqueous globe, in which all the rocks were unstratified, the operation of the elements must have produced the same effects which they do at present; and the result must have been the deposition of alluvia, or the preparation of strata beneath the waters. If it be asked what proof there is of this, I formerly

gave them. The "primary strata" include fragments of strata, and those fragments contain clay, sand, and mica. These are the materials of former supramarine rocks: but there is no evidence to prove that those comprised strata. If the clay which formed the slate of these fragments was derived from previous slate, it would follow that there was an intermediate earth, subsequent to the purely granitic one: if from the granitic rocks, there was none between that and the following condition; and, in this latter conclusion we must probably rest.

The first Revolution which we can certainly infer, elevates these strata above the waters, where they become, in a similar way, the joint materials, with the igneous rocks, for our "primary" ones: while the fragments of strata in them prove that this was a stratified as well as a terraqueous earth. It is the first Stratified earth; but it is the fifth form of the globe, under the present views, as it is the third form of a solid earth. And the evidence appears to be perfect: since in no other manner can we explain the existence of fragments of *strata* in the "primary" strata, and since the same explanation is admitted in all the subsequent cases of general conglomerate rocks. And if we cannot yet find any demonstrable mass of this first set of strata, it is not an opposing argument; since, while the difficulty must be great, under the numerous subsequent revolutions, they have never yet been sought for, from deficient views of a theory of the earth among geologists.

A second revolution, elevating the submarine strata thus generated under this fifth form of the globe, produces a sixth one, being, at the same time, its second stratified form. And here the evidence is no longer disputed: since the supramarine strata of this earth

constitute the "primary" ones of its present condition. In the former sketch of revolutions, being a portion only of a General Theory, this was enumerated as a third mode of the Earth, in conformity to the narrow limits of that view. With the antient geologists, it has been termed primitive, and, under the latest opinions, primary. The philosophical geologist will judge of the propriety of a far other place, at least, though he should not admit the whole of the present views.

I must not, however, conclude respecting this condition, without expressing a doubt, which may possibly be a very serious blank in the Theory of the Earth. I do not think that our knowledge of the primary strata, correct as we have been accustomed to believe it, is sufficient to prove that it is the produce of one revolution; while the antiquity of these, and the numerous changes to which they have been subjected, may well render them obscure. If I formerly suggested this suspicion, hinting at some facts which I could not explain on the present theory, I may here add, that the greatest difficulty I have found, is in trying to reconcile the Chlorite series of Scotland with any condition so simple as that which is here examined.

How far such facts as this may be supported by parallel ones, I cannot foresee, and geologists have not sought, because they had either no theory or a false one. If partial, it may not prove of much import, nor materially disturb the general theory: but if it should be widely confirmed, it may prove that our primary strata are the produce of two, if not of more revolutions, and therefore include two classes of rocks, or two conditions of the earth, at least. Yet having no other reasons than these, I leave this as a hint for future geologists; as I need not say how a proof of the fact might possibly modify the general theory of numerical *successions* as here given.

But there is still another difficulty, which may either be a fresh one, as to a correct theory, or may possibly offer the solution of the preceding facts. The "primary" strata having been formed, partly at least, from previous stratified rocks, there ought to exist masses of those somewhere, not less than of the very primary themselves, after the numerous revolutions which they have undergone. And these should now appear to us as portions of our primary strata; yet only because geologists had not formed a correct theory, from not having observed and reasoned on the fragments in these, and have therefore never thought of such a possibility. Whether they will ever be distinguished, I cannot now foresee: but they ought to be similar to the primary, because their fragments are so, and they ought to be unconformable; so that the case just quoted, with many more that I have observed, may be the very ante"primary" strata in question.

This sixth earth furnishes the materials of those secondary strata which precede the coal; as the time of their production, could it be ascertained, would be the measure of its duration. And a third revolution elevates those strata; thus producing a new and seventh form of the earth, or a third modification of a stratified one. And here we begin first to trace distinctly the increase in the variety of the strata; together with the continuous records of an organized creation. The latter question I must separate and defer: the former may take its place here, once for all.

However various the primary strata may now be, and however different from the secondary, I have fully shown that there is a radical analogy between the two, often indeed reaching to almost an identity, in every thing essential; as also, that the action of heat produces the same or similar changes in the secondary

constitute the "primary" ones of its present co
In the former sketch of revolutions, being
only of a General Theory, this was enum
third mode of the Earth, in conformity to
limits of that view. With the antient
has been termed primitive, and, under
nions, primary. The philosophical ge
of the propriety of a far other place
he should not admit the whole of t [illegible] ing

I must not, however, conclude [illegible] in this
dition, without expressing a dou [illegible] the coal
be a very serious blank in the T [illegible] this forms
do not think that our knowle [illegible] the Earth. I
correct as we have been acc [illegible] first time, geolo-
sufficient to prove that it is [illegible] ; and the science
lution; while the antiquit [illegible] this blot, since it lies
changes to which they h [illegible] story of the globe which
render them obscure.
suspicion, hinting at s [illegible] ation to depress the now
plain on the present [illegible] strata, so that the superior
greatest difficulty I [illegible] may be produced. If I speak
cile the Chlorite s [illegible] in all other cases of revolu-
so simple as that [illegible] that I have dwelt, this is,

How far such [illegible] only result, in this case, as yet
rallel ones, I [illegible] cannot conceive an act of de-
sought, beca [illegible] corresponding elevation: while,
one. If part [illegible] strate this also, in any rocks yet
materially [illegible] second blot in a Theory of the
be widely [illegible] although there is here implied an
strata ar [illegible] during which the submarine strata
tions, a [illegible] were in the act of being deposited,
condit [illegible] conjecture its nature.
reaso [illegible] first chapter, I have spoken of the
geol [illegible] the secondary strata, as succeeding to
mig [illegible] of the coal; thus assigning but one fur-

previous to the last partial re-
written at the very re-
nd printed long ago:
rther reflection
lerstood.

lignite deposits
same manner as the
where the generating
theory of the following
ought to be certain of the
ing to superposition, or geolo-
we are quite sure of but two; in
the green sand: and if I can build
therefore limited to them. But we can
indispensable an accurate knowledge of
deposits of the world is, to a Theory of
If the inferior coal, for example, were li-
Britain, or the two great lignites to Europe,
conditions of the earth, inferred from these, would
partial only, as well as the revolutions: whence,
until every coal, of whatever nature, in the world, is
thoroughly known and accurately compared, we must remain in ignorance, as well of the number as the nature, of the conditions and revolutions engaged in this long interval. Hence the wider and important consideration that follows, hitherto overlooked by geology. If any revolution engaged in any of these coal deposits was universal, such a coal should correspond in geological time, all over the world, and thus be an "universal formation;" since we are sure that it was formed on the surface, be the associated strata what they may. And if the facts should prove such as to render this belief impossible, then the different parts of the world, producing coal at different times, have been under distinct revolutions and conditions, of a partial nature.

There are as yet no facts by which to solve this difficulty: but, in the present case, having no sufficient proof of more than the two great lignite deposits in question, I must suppose, right or wrong as it may hereafter prove, that the others formerly mentioned are coincident with these in time, though referred to the quadersandstein or aught else.

The oolithe coal therefore, implies a terrestrial surface, on the lias, if we please, bearing plants, as the mountain limestone did for the inferior coal. Hence, during the repose of this last beneath the sea, no marine strata were formed, above it, higher than that carboniferous surface, which must also have become a terrestrial one. Was there here a revolution of elevation for that purpose? If so, it would be consonant to all that has preceded: but I can conceive the gradual growth of these strata to the surface, so as to permit of the requisite vegetations, in æstuaries, or on shores; while such appear to have been the birthplaces of both the great lignites, marine as their animal fossils are. I know not therefore, if they who shall criticize this Theory, will allow this to be viewed as a ninth condition of the earth. If there were any facts of disturbance to prove an elevation, it would not be disputed: and that these may not yet be found somewhere, I can by no means admit.

Be this as it may, there is here the same difficulty as in the case of the inferior coal. Marine strata were forming while the terrestrial preparations for the lignite were in progress. Which are they? no one knows. I, assuredly, do not: and it is these reflections, among others, which convince me that our pretended knowledge of the secondary strata is the mere hypothesis which I have so often called it. But of this again.

Now, the same occurrence must have followed this

terrestrial period, as there did in the case of the inferior coal. The lias, with its carboniferous surface, must have been depressed beneath the sea, or the superior marine strata could not have been formed; and thus there follows a tenth condition of the earth, under, of course, the usual doubts as to its extent, during which this vegetable stratum also is becoming coal. If such a depression were sudden, it would be termed a revolution: I know not whether the term is worth a dispute, were it a gradual operation.

At any rate, the marine strata then formed, extend to the carboniferous surface in the green sand, being the place of the second great lignite. And there is here a renewal of the same difficulties as in the preceding case. Was that surface brought up to the light by a revolution of elevation, or it did simply reach it by the increase of the strata? Geology must seek for proofs, as in the former case; I possess no evidence, and am ready to believe whatever is proved: yet, in the mean time, following the general analogy, this should be an eleventh condition of the Earth. And, there is yet another difficulty, renewed for the third time. There are marine strata forming while the plants for this last lignite are growing; and we cannot distinguish them. In any of the three cases, how are these strata, parallel in time, to be known? They are not superimposed on the several coals, nor can they be subjacent. Inferior, or nearer to the centre of the earth, they must originally have been; but if we cannot tell where to seek them now, this at least is plain, that the theories of superposition and succession among the later strata, which even I have been obliged to follow, are mere hypotheses, and that our ignorance of these is infinitely greater than geologists had ever suspected. Thence probably are there many other cases of infe-

rential superposition, not less hypothetical; while this is the only one in which there is ample ground for doubts: the mode of production of a single stratum, the coal, furnishing a point of departure not to be mistaken.

It is now again plain, that a depression similar to the last must have occurred, to permit the deposition of the remaining strata, up to our highest marine surface, the chalk, or more, if more there be; and thence, in the same way, I must deduce a twelfth condition in the earth; the consequence, under similar hesitation as to its extent, of another distinct revolution. And the carboniferous surface of the green sand is now beneath the ocean; undergoing the change to coal. It is only further needful to suggest, that although neither of these last acts of elevation should be admitted, yet that a continuous depression from the carboniferous surface of the oolithe to that of the chalk will not explain the appearances: because the production of the upper lignite, like that of the lower, marks a long repose, and there must therefore have been two distinct depressions. And that the act by which the lower lignite was depressed, was one of revolution, is proved by the disappearance of organic fossils, or of Life, in the green sand: that fact which I had formerly stated as an unexplained one in the Theory of the Earth. Whether it produced irregular positions of the strata any where, geology does not yet know, and must not assume of all places. And surely I need not here repeat, that although the whole of these views of the conditions of the earth might be nullified by the antient hypothesis of "the rising and falling of the ocean," this has been sufficiently proved to be impossible. They would also be nullified, should there be no real superposition from the coal upwards, and should the whole

vertical sequence from the red marl to the chalk be hypothetical instead of actual, as part of it assuredly is. But I must believe, with other geologists, that there is enough proved for this purpose; although I have not seen all that I could wish respecting these strata.

If the intricacy of these last changes has demanded some space, what follows is comparatively simple, as it is indisputable. What numerical order the necessary revolution should hold, must now be doubtful; but it was an extensive and a great one; since by this was the inferior coal elevated, with all that was needful, beneath it, and with all that now exists above; extending, certainly, to the chalk, and probably to some superior strata, in particular places at least: while, this defect in our knowledge leaves another blank to be supplied, as to a perfect theory. And this condition, though assuredly not the exact Earth which we inhabit, is at least the basis of the present order of things, as it is a thirteenth condition.

But here the difficulties of discovering a just theory are renewed. There has been a subsequent revolution, or there have been more than one: but which of these is the fact, our knowledge does not yet enable us to determine. The condition of that Earth which is, at least, a fourteenth one, differs from the preceding in those two essential facts which constitute the elevated "tertiary" formations, together with the Italian, and probably some other, alluvia. But, at present, we have no evidence to prove whether there was, here, one revolution, or more, with corresponding conditions of the globe, and, therefore, an Earth, or Earths, different from the preceding, and anterior to the creation of Man. Whether this blank will be filled, or not, hereafter, I am unable to foresee; and it is not here my business to suggest the means. It is sufficient, that

in conformity to my design in this Sketch, I have pointed out to Geology what it has neglected. It may possibly be hereafter proved, that there was, at least, a fifteenth condition, prior to that earth which was prepared for the habitation of Man. And if I need not recapitulate the Evidences for these views, I may at least say, that from the fourth condition onwards, it consists in facts which all geological philosophy has admitted as valid proof, as far as it had applied them; though not having before perceived that they were of such wide application.

Still, there is another question to be asked, which I cannot answer. St. Helena, Ascension, the Canaries, and many more, with many of the coral islands of the Pacific, have been elevated, either totally or partially, at some not extremely remote period, or periods. Do these actions belong to the last condition, or are they of posterior date, or dates; and, if so, are they also anterior to the creation of man? Do they, in short, imply a further condition of the earth, previous to the actual one? Geologists have never even thought on this subject: to this hour, they have scarcely thought much more deeply than the Werners, who had dreamt but of one earth and one condition, from the prime creation to the present day. I am sorry that I cannot inform them: but I have at least shown them that there is more to be yet learned than they had ever imagined.

Reserving the theory of the Organized creation, such is at present the basis and essential portion of a Theory of the Earth; since it is the history of its progress, as a planetary globe, from its first apparent production, onwards, to our own Creation. But a view of the probable causes and the further nature of those revolutions is also necessary; while if, here also,

there are some imperfections, the essential facts are matter of undisputed Evidence.

There can be nothing in the nature of Revolution, strictly speaking, till the third condition, in which it is presumed that the unequal expansions of the interior fluid where producing mountains during the progress of cooling: while I must here mark, as evidence of such a proceeding, that the Moon presents this very character; being evidently a globe with a solid irregular surface most obviously produced in this manner, at very different periods, without stratified rocks, and, thence, rocky through the cooling of fluids alone; while the evidence, not merely for the fact, but for the progression, and for its very cause, is seen in its volcanoes, successively produced, and still occasionally active.

If such expansion, with effusion of igneous rocks, is thus the cause of the subsequent Revolutions, so, from the third form of the earth onwards, it becomes demonstrated, and as to each successive one, with some hesitation perhaps as to the lignites, by facts which no philosophical geologist now disputes, though I have here multiplied the number; yet, in no case, without the same evidence. It is sufficient to say, that the immediate demonstration rests in the volcanic rocks, and in the effects of their powers on the stratified ones; and that the various analogies, both in the produce and in the effects, extend this absolute and visible evidence, retrogressively, though the whole system. Where that evidence was formerly doubtful or disputed, I have now also completed it; by tracing the whole of the expansive actions backwards from the Coral islands, and by showing that there are a sufficient number of distinct productions of igneous rocks, succeeding each other at intervals of time, to

account for every new modification which the Earth has undergone; with the preceding doubts, only.

If, thus far, the theory seems perfect, there is an involved difficulty which geology cannot yet solve, and probably never will; since I cannot foresee whence evidence can possibly come. The expansions, or Revolutions, in the first, solid condition, or third form of the Earth, ought to have been numerous and long continued, on general principles; it was a durable state of commotion, as of solidification. In the subsequent ones, the apparent effects are those of a single action of the same nature. This is all that we see: yet if allowed to infer from the present nature of volcanic action, it is more probable that each such condition of revolution was tedious, and the disturbing motions successive.

Further than this, I can say nothing: but I must re-urge that difficulty which forms an additional blank in a true Theory of the Earth; while, as to this also, I can foresee no chance of evidence. Was the whole Earth, or only a portion of it, involved, in all those cases which I have here marked as successive conditions? This is a most important question: for the blanks which it leaves unexplained, are enormous; inasmuch as it includes the weighty fact, whether the revolutions concerned in the coal and in the lignites were limited, or not, to one portion of the globe, as the posterior one which acted on Italy seems to have been much less than universal. On this, I am powerless: and can only remark, that every other one appears to have been universal, from the presumed existence of similar strata all over the globe, as far up at least as the red marl, itself a portion of that state of the earth which is nearly the latest.

But there is one important fact connected with these

actions, which I must not pass without notice: while, if the cause be unknown, the broad deductions from the remark are as new as the fact is certain; be its exact nature and bearings what they may. If it is a subsidiary fact in a Theory of the Earth, it is nevertheless, deeply implicated with any pretence to perfection in such an attempt. If subsidence as well as elevation has been proved, thus establishing some probable system of counterbalances, or of alternations in a moveable solid surface, so must there be some peculiarity of structure, on an enormous scale, in some portion of the earth; though a structure can only be conceived of that which is solid. And the evidence of this consists in the extended uniformity of the elevations of strata, sometimes producing corresponding mountain ridges; as the frequent linear directions of volcanoes are evidences in support of this view, utterly obscure as the cause and the exact nature of the fact may be.

Thus far I have stated, as clearly as I can in so brief a space, the entire foundation of a Theory of the Earth, with its Evidence. If still reserving many subsidiary points, that I may keep these matters disentangled, I must now go back to what is, in reality, the object of the highest ultimate interest, namely, the theory of the Organic Creation, as far at least as it is connected with the progress of the Earth, or, as far as it is a truly geological question. All beyond this appertains to the Natural history of organized bodies; and it is fully time that this should be separated from what is pure geology, that, as a distinct science, it may receive due attention from those who are really competent to pursue it.

Unfortunately, this portion of the theory is very obscure, and is for ever likely to remain so; as the evidences are also in a great measure inferential and unsatisfactory. As to the existence of such beings in

former conditions of the Earth, it is perfect, wherever we find their remains; whatever other difficulties may subsist on collateral questions. But I know not how to treat the entire subject, without commencing with that presumed fact, being my own belief, that every limestone has originated in animals, and all coal, if not all carbon, in vegetables. I cannot now repeat the reasons: they have preceded, under all the arguments that I possessed: and those who will not accept of this subsidiary theory, can therefore cut off from what follows, all that depends on this supposition; while, if they rank it with the blanks of the Theory of the Earth, all else, founded on the presence of organic fragments themselves, will still remain.

The micaceous schist of the primary strata contains fragments of limestone; and there ought therefore to have been an animal creation as early as the fourth state of the Earth or, in the very first terraqueous globe, in which there were only igneous rocks. We may believe them purely marine; while if there is no analogous evidence of some vegetable creation, the peculiar circumstances leave that negative of no weight. To many, I fear the argument from Final causes will possess no force in support of this view: but if the very purpose of the Earth, in the plans of the Deity, was to be the habitation of Life, we ought to expect some inhabitants, as soon as this new planet was capable of receiving any; and these proportioned, in quality and numbers, to its capacity for supporting them. With myself, I confess, this argument always carries great weight, wherever it is applicable: I need not tell the metaphysician when and why it fell into discredit; and I would rather not say why there are philosophers, philosophers in all but their views of a Creator and Governor of the world, who will not receive it now.

In the early portions of the "primary" strata, there are limestones in considerable quantity, and therefore formed under the ocean of the second terraqueous, or fifth earth. In the later, there are organic animal remains in abundance; whence that Earth was assuredly inhabited, during at least its later periods. I must presume, that it was thus inhabited at as early a period after its change as it could have been; partly in consistency with what I have already said, and partly because, having demonstrated that it is the effect of heat to obliterate organic remains in limestone, and that the earlier primary strata have been especially under its action, their absence forms no objection. Thus also does the absence of such bodies from still earlier strata, cease to be a difficulty; as these facts render the present theoretical view of the origin of limestone more probable. And in further support of such a view, let it also be remarked, that as the organic creation necessarily increases during any period of repose in the earth, so is it true that the limestones augment in proportion as we ascend in the order of these primary strata; as the organic bodies also remain where the heat must have been least. I need only here refer to some former facts respecting the existence of organic animal fragments in even the earlier primary strata: and thus also, from analogous ones respecting primary coal, content myself with simply inferring some vegetable creation. Whether this was marine only, or terrestrial also, will never now be known: but under the preceding metaphysical argument, I can never believe that there was a dry land, covered with alluvia and soil, as it must have been under degradation, which was not occupied by plants at least. If it possessed terrestrial animals, they could not have been preserved, as I formerly showed; so that this negative

also, proves nothing. And these have been the disputed points. Every one believes in the existence of organic beings, both vegetable and animal, in each subsequent stage of the earth; and I may therefore be the more brief in my remarks on these.

The organic creation of the sixth form, or third terraqueous condition of the Earth, is found in the old red sandstone and its subsequent limestone. The remains prove a marine creation of animals, but not a terrestrial one: yet, as before, I cannot allow this negative any weight against the general argument. Vegetables were created for food to animals; it is the final cause: there are terrestrial as well as marine vegetables; and therefore a terrestrial animal creation should have existed.

Having already stated my uncertainty whether the seventh condition was partial or general, it is here also that there commences a great obscurity in the general Theory, as far as it relates to an organic creation. We have evidence only of marine animals, contained in those, yet unsettled, strata, which must have been forming under the ocean while the preparations for coal were proceeding above it, and of such animals of fresh waters as are also preserved in these. Were there terrestrial quadrupeds? I confess that even my own faith in the general argument, as to this condition at least, is somewhat shaken by the negative fact, that their remains have not yet been found in the coal strata; since the circumstances appear to have been favourable to their preservation. But I will not speculate: since this is no part of my plan: it is another blank in a Theory of the Earth, and I leave it a legacy to futurity. Of a terrestrial vegetable creation, the records are most ample, since we owe the coal to it.

From the eighth condition, in which the coal is be-

neath the sea, onwards, the earth has been amply inhabited at different periods, though we may not be able to separate the records of this state, or these states, now preserved in our uppermost secondary strata, from those of the former. The lias is, itself, evidence of terrestrial quadrupeds; though the animals, hitherto found, are, solely, amphibious, or flying ones: but I need not repeat, that we have no right to decide on the non-existence of others, because we do not find their remains; as it is superfluous to say that there also existed a creation of terrestrial vegetables.

In that nearly final condition of the Earth in which the last secondary strata had emerged, we are assured of an extensive terrestrial creation; while, beyond this, I need not now enquire, since the other forms of life are implied: as these remains occur in that existing condition, respecting the number of which I need not now repeat the doubts; being those found in certain tertiary strata and marine elevated alluvia, which have excited so much attention. I have formerly said, on the subject of such deposits generally, that the negative evidence of the non-existence of human remains is not sufficient to prove that the creation of Man had not occurred at this period: but I think this general conclusion will be made by all philosophers grounded partly on history, and partly on geological circumstances which I need not now repeat, namely, that, our own Creation was not appointed till the last great, if partial changes, had been completed, and that it belongs to a condition of the earth removed by at least one stage, if not more: which will therefore find its numerical place, as it may hereafter be decided respecting the later revolutions.

It does not appear to me that the evidence respecting the nature of these organized beings can now go

any further; and it is not within my plan to speculate beyond proofs, nor to state the prevailing *opinions* respecting successions, improvements, or whatever else, in which geologists have indulged. There is no Evidence: and if this is to be considered a needful portion of a Theory of the Earth, I believe that it is for ever likely to remain a blank. Whatever has been proposed is fanciful, if not false: and, when pretending to proof, resting on that negative evidence which is nothing; since too much must have been lost, to allow of those conclusions which have been so wantonly or ignorantly drawn.

On this portion of the Theory of the Earth, it remains to ask whether there was a new creation for each condition, or whether it was uninterruptedly progressive from the commencement. There seem to me to be two geological arguments for extinctions and renewals: it is another enquiry whether these apply to each condition here enumerated. The first is, that we cannot conceive a general revolution from fresh formations of igneous rocks, without a total destruction of all life; and the other, that we find certain new sets of strata commencing without the presence of organic remains, while these increase in the progress of time. To apply these arguments is less easy: while I admit of no third one, derived from the characters of the remains, since it can have nothing to rest on but the negative evidence which I have so often rejected, and since every thing hitherto advanced on this subject is purely hypothetical. Admitting these arguments, we ought, I think, to conclude, that the organic creations of the two first inhabited globes were really destroyed and renewed. This is probably true of the third also; but at this point our doubts must commence; because it is here that it becomes uncertain

how far the revolution of the earth was general: yet if any portions of the red marl or the magnesian limestone were then also forming, the second argument will be in favour of such a supposition. Be this as it may, I think there cannot be any doubt respecting an entire destruction, at that period, the fourth revolution, which produced the eighth form of the globe, when we see that its universality is indicated by the wide range of the red marl, and find that this great deposit contains few or no organic bodies. And it seems to me that we must argue in the same manner respecting the green sand, similarly circumstanced, in this respect, to the red marl, as I shall again notice: while if these conclusions rest on the second leading argument, we must infer, from the first, that the last revolution, elevating the chalk, must have been attended with an universal extinction of life, since only an universal production of igneous rocks could have thus displaced the enormous masses here implied. Beyond this, there seems no reason to presume on the entire extinction of what had been created after the last event of this nature; of those races which inhabited that Earth which is the basis of our own. All further revolution appears to have been partial: and it is perhaps even evidence of this, that some at least of the very same species preserved in these newest strata, "tertiary," and marine-alluvial, are identical with existing ones.

Thus then, if these views are correct, I have demonstrated four extinctions of antecedent organized creations, while there are two more, perhaps less satisfactorily proved. Each of these, consequently, admitting the whole, implies a previous distinct creation; while, as one must be added, subsequent to the last general revolution which elevated the secondary strata, there

should have been seven distinct creations of organic life. But there is yet one more, if, as seems to be believed, the quadrupeds of the tertiary strata were not created till a later period; while the creation of Man and some other races of animals will still remain to be added, under the general geological and historical arguments which I need not now detail. But I desire to be brief on what is most doubtful: and I therefore leave this, with much more, to those who may prefer a system, alternately theory and hypothesis, under the name of Theory, to a chain in which many demonstrated links are separated by some broken ones. This only I ought to remark in general; that whether interrupted or progressive, or both together, the organic inhabitants of the earth appear to have augmented, in numbers, in variety, and apparently in perfection, if not regularly, from the commencement: while we might even have decided on this *a priori*, knowing that its quality as the habitation of life, had been progressively improved. Respecting imaginary changes of temperature or axis, I will add nothing to what I formerly said: there is no Evidence for either, and there is opposing evidence: yet if I formerly adduced the non-production of peat in hot climates as an argument, let me so far correct this, as to state, from some more recent information, that a kind of peat is generated in the Indian Archipelago; yet not on such a scale as to invalidate it.

Thus have I, to the extent of my knowledge, sketched the fundamental and general Theory of the Earth, and its progression to our own days, from that first state which we may infer to have followed the act of absolute Creation. But there are many subsidiary points yet demanding notice, which, if I have separated them for the sake of clearness, can be easily transferred to

their places, in the mind of any reader. I must first examine what belongs to the theory of each distinct condition of the earth.

Of the sixth, being also the first affording any remark, I have said all that I know, in suggesting that its strata, consisting of our primary, must have originally resembled the present secondary ones; and I will not dwell on what any geologist can supply, or conjecture as well as myself, respecting this condition of the earth. But the conglomerate of the old red sandstone proves that tumultuary state of the waters, at the previous revolution, whence I have endeavoured, by analogy, to deduce the causes of certain modern alluvia: while the sufficient absence of organic bodies is the argument for an extinction of life at this period. If the mountain limestone marks the gradual increase of life, and, as I formerly suggested, the production of coral banks, so do some of its remains prove that it was, in some places, formed in shallow æstuaries, indicating therefore rivers. But it is superfluous to say that some of them also denote a terrestrial vegetation, since it is on the dry land of this Earth that the preparations for coal are in progress.

If the theory of coal is therefore included in this subsidiary portion of the general theory, I need but repeat, most briefly, what I have formerly explained at great length, and under ample evidence. Be the plants what they may, they were the inhabitants of moist lands; of the marshy margins of æstuaries, and probably also of inland lakes. Their remains were deposited as peat is now; and where coal beds alternate with rocky strata, it is because such beds of peat were occasionally inundated by earthy matters. But I can see no method of explaining the great depth of these deposits, except by slow subsidences of the land, per-

mitting fresh successions of vegetation at the same low levels: while, if I may again resort to the argument from final causes, the importance of the ultimate object will justify such a proceeding, and in the case of the lignites as in this one, under what we must believe of the Designs of the Deity in the creation and arrangement of the Earth.

If I can but repeat my entire ignorance of the condition of the earth after the depression of the coal strata, it is here at least that the vegetable deposits were mineralized; while I have shown reasons for believing that this change was not induced by heat. But the great blank in a Theory of the Earth which here remains to be filled, respects those strata which must have been forming at the same time as those intended for coal were growing, in the preceding state of the earth, and which we cannot now distinguish from those which have been subsequently deposited: while there are the same precise difficulties also, respecting those periods in which the two great lignites are forming.

Respecting the strata which follow the coal series, a little will suffice, after the remarks in a former chapter on the subject, and the preceding ones on the conditions which include the lignites. If the inferior limestone, not alternating with earthy strata, and containing coral, appears to have been formed by coral banks, those that contain shells, and include earthy strata, have been produced jointly by the growth of animals and the degradation of land. If I assigned two possible causes for the magnesian limestone, I even now hesitate whether, being a probable produce from the mountain lime, by degradation, it might not also have undergone the action of heat; so much is there, in the characters of the red marl, to lead to a suspicion of this

influence. And if I consider this great deposit, with its salt and gypsum, as constituting one of the greatest blots in a Theory of the Earth, let it at least be declared that we are in a state of utter ignorance; though let me repeat, that its wide extent, added to characters so peculiar and so uniform, indicates some peculiar condition in the earth, at, perhaps, the periods of its formation and elevation both, which marks our ignorance even more than the presence of these minerals.

If the lias denotes a marine deposition of ordinary alluvia, accompanying the increase of marine animals, the presence of terrestrial ones in certain portions of it indicates nothing more than its superficial position at these points; proving also nothing respecting the nature of that creation. But while the oolithe, or whatever analogous series may exist elsewhere, marks the gradual increase of marine animals at least, its oolithic portions possess a peculiar interest, connected with those depressions which I have argued in the preceding view of the Earth's conditions. These can only be formed near the surface, or on sea shores, while, as they are now vertically separated by solid calcareous strata, it indicates the very changes of level in question, during the progression of this great series; and thus tends to confirm these views; as it also corroborates the former theory of the mode in which the successions of coal beds have been produced.

The absence of organic bodies and limestones from large portions, at least, of the green sand, marks, as I already said, the importance of the revolution preceding the deposition of this series. The subsidence of the first lignite seems to have destroyed life, as that of the inferior coal did; and the results are seen in the green sand, just as in the red marl. How far this

might have occurred at the depression of the former, and antecedent to the deposition of the chalk, must remain a question, till the interval between the uppermost lignite and the chalk is better known than it seems yet to be. In the preceding one, at least, supramarine rocks are degraded, through a long period, but marine animals do not exist, or have become rare. If I formerly called this a great blank in the Theory of the Earth, I cannot but consider the present view as proved: while, under a revolution of this character, we ought perhaps to expect what has not yet been found; discordance of position, as in other cases, and this now forming the real blank. If the general relation of the chalk to the green sand, marks, like that of the oolithe to the red marl, the gradual increase of life, after extinction, I need but slightly repeat, that the clays, sands, and gravels often found above it, must have been superior marine deposits, whether they are now rocky strata or not, and that it is not therefore the last. I have left little to say respecting the lignite coals. Except in some few cases of transportation, and in others, where they have been derived from marine plants, their origin is similar to that of the inferior one, if perhaps they are always the produce of shores or æstuaries, while the other is often lacustral. Taking as our type, the great floats of wood brought down by the American rivers, we can conjecture respecting those of transportation: but this source is excluded whenever they are repeated with intermediate rocky strata, and with vegetable fragments and beds of shells, marking a regular stratification under repose; as it is also, under the great extent which many occupy. But for the certainty of this, the former view of revolutions and conditions, from the coal to the chalk, would be a fable: while in this case, as in the inferior

coal, that system of depression which so many other facts prove, explains the successions of the beds. Respecting the chemical theory of all coal, I have clearly traced it from peat, and, when necessary, through the organic lignites; proving also that the entire process of bituminization is the effect of water, not of fire; whether or not the former is the exclusive cause of the present mineral character.

There remains another subsidiary point to be noted; most conspicuous in the more recent strata, or later conditions of the earth, if, probably, not less true of every set. How far it may affect any of the present views of a Theory of the Earth, will only be known when the whole globe has been better examined than even Europe has. Hitherto, with some knowledge, there has been still more of presumption. In spite of all the warnings of philosophers, it is surprising how seldom men have enquired why they believed, how inveterately they have persisted in the imaginary "truths which they have inherited without any industry or acquisition of their own:" assenting without evidence, and persisting against it. But "all the world are born to orthodoxy: they imbibe at first the allowed opinions of their country and party, and so, never questioning the truth, not one of a hundred ever examines."

I have fully shown, that the necessary circumstances under which every deposit of strata must have been formed, render it impossible that they should be identical, either in quality or order, beyond certain limits; that, in reality, all of them are more or less partial, while some are conspicuously so; and that they cannot, either in consistence with this, or with the laws of animal life, be identified, under remote positions, by means of their organic fossils: and the conclusion therefore is, that under every condition of the Earth, the deposits

of strata have been independent; regulated by the lands that produced alluvial matters, and the seas that received them and bore animals.

Among the primary strata, this is proved by the fact, that in no two parts of the world, are the successions similar: while the correspondence of mineral quality proves nothing, as being the result of the universally influencing cause to which they have been everywhere subjected. Sandstones, shales, and limestones, must have ever been the germs of all strata: and all beyond this is the produce of heat. And the variety of order in the primary strata, now represents a similar variety in those which were once secondary.

It is not yet known whether or not the old red sandstone and mountain lime occur all over the world: and till this be ascertained, even the preceding theory may be untrue, as far as it presumes on an universal revolution at this period; just as it may be in the case of the coal strata. But it is beyond this that the greater difficulties commence, and the greater assumptions exist. Even in Europe, I have shown that the identity of the upper strata is often conjectural, and often falsely asserted. And Geology, with geological theory, must remain greatly defective, even in the most fundamental facts, until their analogies at least, since I cannot admit of wide identities, shall be traced throughout the world. If here also, therefore, a Theory of the Earth is defective, it is important to point out, as strongly as may be, one of the hypotheses which now especially obstructs its progress. I need not say that my own sketch is, consequently, deficient in this branch of the total theory: yet I have not made the hypothetical division of England a rule for even Europe, however appearing to have done so, and not also presuming beyond this, since I consider the continental deposits which English

geologists have forced into a correspondance with our own, as sufficiently analogous to let this branch of the theory stand, to the extent that I have assumed.

But I must note this. The secondary strata have been divided into groups, termed "formations." This is as much hypothesis as the forced correspondence of remote deposits of strata: while these arrangements, which have often also been changed, are so purely fanciful and capricious, that I cannot conjecture, even what the assumed ground is; what the reference to the act of formation or production; if indeed there has ever been one. Nor can I see any ground for such groupings, but those which I shall here state: although, whether the following principles be admitted or not, there cannot possibly be a natural group of any rocks, including, within two portions of these, either of the great lignite deposits; since these are the very evidences of a terminated marine stratification. Nor can the received groups be natural, or just ones; from what I have proved respecting the deposition of submarine strata while the coal and the lignites were forming on the surface. They have included, as following in vertical order, strata which were, most assuredly, not thus formed, and which therefore, however now *inferred* to be, inferior ones, never can, in all places, be found in a state of actual inferiority. In no sense then, can such a group be a "formation," if that term is to possess any meaning at all; since the strata associated in them were once, in every sense, independent. And if it be a word to serve some artificial purpose, that is an evil one; because it becomes an hypothesis which is a demonstrated falshood, and therefore impedes the acquisition of real knowledge.

If such have been the arrangements, I do not pretend to substitute a better method of grouping the upper

strata: not only because I cannot trust the information collected by such observers, under such hypotheses, or because my own personal knowledge is insufficient, and that I do not see what is gained by philosophizing through the eyes of others, but because I have proved that we know nothing of those marine strata which are of parallel time to the coal and the lignites. But the principles of grouping seem simple, as far as any deposits are truly vertical in position; without which, it is plain that we can at present do nothing. And if geologists should receive them, time may produce what we yet have not, and give us at least something nearer to the truth. It is for this very purpose that I have laboured to state our ignorance as well as our knowledge, and also its exact nature: it is not the easiest task in science, as every one knows: while unfortunately it is also a considerably offensive undertaking, to those who prefer the semblance and the reputation of knowledge to its possession.

A sandstone and a shale, singly or alternating, mark the degradation of terrestrial rocks; a limestone indicates the production of subaqueous animals under tranquility in the earth: and a coal denotes where its surface then was. Suffering the inferior coal deposit to remain as a single group, the space between two carbonaceous strata, and these being also untransported ones, is therefore a group, of which we are sure: as we are in the case of a single and separate parallelism among the inferior strata of the earth. If there are to be large groups on any other principles than these two, let some one else point those out; for I cannot. And if smaller ones are desired, the principles seem to be these. First, that any great mass of strata, in truly and tangibly vertical order, geologically speaking, which is predominantly or conspicuously calcareous, marks a

period of repose in the earth, in which animals were multiplying, and is therefore a great deposit; as it may be a group by containing interposed shales and sandstones; these marking the joint degradation of the land: while an excess of non-calcareous strata needs not give rise to a separate one. Secondly, that another group can be formed of a continuous mass of alternating shales and sandstones; animals having disappeared, or become rare: while here also, a few calcareous beds, especially in the upper portions, need not impede such a separation. Yet should the limits be undefined in practice, thus leading to differences of opinion, we must console ourselves by recollecting that we cannot do more than Nature has done. And if Geologists will now show that they have distinguished the upper strata in this manner, we shall begin to understand each other: or rather, if they will hereafter do what they have not yet done, and further, trace the geographical limits of these groups, principal or subsidiary, in the world, or even in Europe, we shall then discover how far remote strata and sets of strata correspond, and know, at least, somewhat more of the agreement of "Germany" and "England" than from a comparison of their respective cockles. But I shall not end these remarks without adding, that if the circumstances which I have pointed out as to the conditions of the earth following the coal should be established, the classification formerly given will require essential alterations.

The last subsidiary branch of the Theory of the Earth, as far as anterior to its present condition, includes the partial deposits, so much confounded under the vague term "tertiary." I was unwilling to propose the entire disentanglement of this subject formerly: I must here endeavour to do what a general Theory demands. That some deposits more properly belonging to the alluvia, should coincide or be con-

founded with the true tertiary ones, is what I cannot help; when, in some of the cases, the causes are identical. I am still bound to separate these from the alluvia, at some point: if I have not chosen the best, it will be but for others to alter the order: the theory itself will not be affected.

A lake receives alluvia, and forms strata, just as a sea does; and lakes have done this in antient times. Such a lake also may have been fresh or salt; or it may have been salt at first, and subsequently freshened. Partial elevations of land have occurred, demonstrably, in times before our own: and, affecting these, they are elevated lacustral deposits, salt, or fresh, or both. Similar strata are, and therefore have been, produced in æstuaries. Under the same circumstances, they now form tertiary deposits; while variations of character with respect to the marine or terrestrial qualities of the strata, may have arisen from terrestrial inundations, or from marine ones, or from vacillations in the level of the land. And these seem to me all the deposits which, in a just Theory of the Earth, should occupy this place: because they are included within certain antient revolutions: while it will be more conformable to an order tracing the progress of the globe, to rank the deposits of lakes which have been drained or filled, with the alluvia; as we rank travertino.

Thus, with the exception of one important subsidiary point, as yet inexplicable, and of some others, of a subordinate nature, which I hope to explain, I have terminated this sketch of the Theory of the Earth, down to the period of its commencement under the existing condition, with the reservation formerly made respecting the volcanic islands. These minor matters I shall here note, as briefly as possible, before I proceed to that which concerns our own days.

On the theory of mineral veins, so important as to

form one of the greatest blanks in a general Theory, geology has not even a rational conjecture. I have already collected and analysed the essential facts on which it must be founded, as far as these are known; this at least had never been done: but I must leave the rest to posterity. That the theory of certain springs is another blank, it is sufficient to note.

I have shown that the unstratified rocks are all, equally, of igneous origin, carrying on the chain backwards from the volcanic ones; that the mineral characters of all the species are analogous, and pass into each other; that a mineral character in any one has no necessary dependence on its period of production; and that all have originated in the interior of the globe, with some local exceptions of earths fused *in situ*. That, short of such absolute fusion and loss of form, antient strata of a simple character have become what our primary ones now are: while those which have been most exposed to heat have undergone the greatest changes, as, on the other hand, those which have felt less of this influence have suffered the least. But also, that, in all cases, where they contain independent crystallized minerals, these have been produced by heat; possibly, often short of effecting their absolute fusion. And that all this is confirmed by local facts, which also give the analogous theory of certain partial rocks, such as jasper, chert, and siliceous schist. Whence also, especially, from the local fusion of conchiferous limestone into marble, are drawn the inferences respecting the organic origin of the earlier limestones. And thus, referring to the several chapters for fuller details, the theory of each rock is as follows; as far as they are not altered by water.

All the granites, porphyries, and traps, with little exception, were fused and effused fluids, and their va-

rieties depend, partly on the original materials, and partly on the times and modes of cooling. The exceptions are those where the materials have been fused without effusion: in which cases, fragments of the original strata sometimes remain.

All the primary strata having originally been what the secondary ones now are, the latter demand the first place. Their materials are sand alone, or sand mixed with clay, or clay alone; or either, or both of these together, mixed with calcareous earth, or with hydrocarbonaceous matter, or with both, or lastly, carbonat of lime. In these cases, they are strata of a fine texture: but they are coarse or conglomerate, by containing the fragments, instead of the materials, of previous rocks, as they may also contain the minerals of those. The latter demand no further notice: the former can consist of nothing but sandstones, shales, and limestones; each, and the two former, especially, varying in quality according to the ingredients. These two are separate strata, in consequence of the differing specific gravities of their materials in water, and because those have been the produce of former rocks. This is also partially true of the later limestones at least: but the great mass of these is the produce of shells, breeding beneath the sea; while, often preserving those bodies, they are conchiferous limestones. And the same reasoning applies to the tertiary strata. I have attributed their consolidation to solutions of silica and of carbonat of lime, or to pressure, or to both united. But they have possibly, or probably, been exposed to heat, as high up as the old red sandstone, if not higher, so as to have suffered changes of texture: the arenaceous strata thus acquiring the aspect of quartz rock, and the shales that of primary schist.

Yet whereever I have suggested this possibility, or probability, in any case, even in that vexatious one of the red marl, let this never be forgotten. The mountain limestone contains shells; and shells are obliterated, even by the passage of trap veins, as I have amply proved. Therefore such heat, if it did act in any case, did not act as it assuredly has done on the primary strata, extensively, or universally. And it might have affected one deposit, such as the red marl, without involving all above, or even below: since the non-conducting property of rocks, so much overlooked by theorists, will account for this, and much more. The whole solid portion of the globe needs not have been affected by every effusion of ignited and fluid rock. And any one who will reflect, for himself, on this, as on many other subjects, here stated so briefly as to demand deep reflection, will comprehend what I could not have fully explained without occupying an entire volume. I know not that I have acted right in suppressing that volume, and thus condensing such a mass of thought. But it will give readers the opportunity of thinking: of that, by which information becomes knowledge.

With respect to the primary strata, their present nature and successions will indicate, with no great difficulty, what those where when in their first condition. And the nature of the original materials, with the degree and mode of the heat to which they have been exposed, will serve to account, as well as we can now expect, for their differences.

Gneiss, when granitic, is, thus, an uneffused granite: as it approaches nearer to micaceous schist, the same theory serves for both, and also for the analogous schists; or the fusion has been less perfect or less durable: while, in each case, the parallelism of the mica, like the laminar arrangement of the felspar, and the

casual minerals, is the result of crystallization. Hornblende schist is the produce of fused clayslate; being compound or simple under different modes of cooling, as, possibly also under some difference of materials; and though quartz rock has been exposed to heat, it has not suffered fusion. Argillaceous schist has been in the same state as micaceous schist, where it contains crystallized minerals, and, possibly, always; since even shells would not be destroyed in clay, though they are in limestone. Primary limestones have been in fusion wherever they contain crystallized minerals, and probably always; with the obliteration of their shells. Diallage rock appears to be analogous, both to granite and gneiss: that is, to have been fused, either *in situ*, or with effusion; and this appears true also of serpentine. And pitchstone is a trap, essentially; but the causes of its peculiar character and limited place are not quite apparent.

It having been long admitted that the action of heat, through igneous rocks, affects strata in contact, I have shown that it also produces several concretionary structures; among which, the columnar and the spheroidal are most particularly demonstrated; as is the fibrous, and also the schistose, if less common: and further, that under any cause, the schistose structure of the primary slates is concretionary. I have also proved that such concretionary structures occur in rocks heated short of fusion, and, moreover, that this passes gradually into the crystalline; proving a connection, rather than an analogy, which adds to the difficulty of all our theories on the subject of crystallization. If I have further shown that flexures might have been produced under the influence of water and fire both, so have I proved, that the crystalline polarity extends through large masses; whence, as I have just said, the parallelism of mica in the early rocks depends on this cause.

Such is a brief summary of the involved points in the theory of the rocks of the Earth, in as far as they are in their original condition: but that theory, as they are now visible, is not perfect, till the posterior action of water, and apparently of air also, on them, is considered.

I have shown that water, so loosely united as to be separable by evaporation, exists in every rock, though of igneous origin, as it does even in quartz. Holding certain earths in solution, it thus deposits them in cavities: and thence the theory of calcareous and quartz veins, under whatever form; as also of the amygdaloidal nodules, however complicated: these including the agates and the septaria. The crystals and stalactites of cavities are but the same things, uncompleted: and, in this latter case, I have shown that chalcedony entangles living vegetables and animal remains. I have however left a possible exception as to quartz in the amygdaloids; having proved that it can be crystallized by sublimation.

If deep-seated rocks thus possess a different character from superficial ones, I have also proved that the included water sometimes decomposes them within the earth, without access of air; selecting even a single rock, stratified or igneous, while superior ones escape: thus explaining many former difficulties in geology, and ending many disputes. I have proved a still more important fact respecting some of the igneous rocks; though yet uncertain how far exposure to air also is necessary. This is, that crystalline traps acquire an earthy aspect, even to enormous depths, in this manner; producing those claystones, the character of which had, not unnaturally, caused many to deny this origin; thus relieving the theory of trap from a great former difficulty. And I desire here to sug-

gest, whether this also may not reconcile the frequent earthy character of serpentine, with that former dependence on heat which I have also proved.

I need make no new remarks on the decomposition and disintegration of rocks though exposure to water and air: but having shown that these can separate solid scales from the surfaces of many, I beg to point out the explanation of this as a problem for future geologists; while I have thus also proved that peculiarities of decomposition do not always depend on concretionary structure. And to conclude on this division of the Theory of the Earth, if I may now refer, backwards, to the list of demonstrated facts which proceeded this sketch, it remains to enquire of the present condition of the globe, as far as there is any thing which demands to be included in a general theory. And, first, of the alluvial strata.

The elevation of the secondary strata must have brought up the submarine unconsolidated alluvia also; while further, no such movement could have happened without the production of currents in the ocean. Thus have I explained those alluvia of obscure origin to which hypothetical causes have been assigned, be their characters or places what they may: as this also tends to explain certain traces left on solid rocks.

These must be the earliest of alluvial matters; but I have proved that partial elevations have occurred since that period; partly through the appearances of the tertiary strata, and partly by the nature of their organic remains. Since these cannot be separated at present, either from the former or among themselves, I can but name them in some probable order; while remarking that the elevated substances are either solid or loose, whatever the causes of the consolidation may be. Geology will probably never determine what the

periods, or the order, have been: but the facts exist in Italy, in many islands of Africa and the Indian archipelago, in the West Indian islands, and in the Coral islands of the Pacific ocean. The power is that of volcanoes, of different periods; and, for the elevated substances, I must refer to preceding chapters.

From this point, there can no longer be any assignment of dates, since each class of alluvia is in daily progress, somewhere; as all have been, from the commencement. I therefore muster them as appears most convenient. Lakes have been drained or filled, at all periods, as the same events are still occurring. Their strata, solid or loose, and sometimes containing organic bodies, have been confounded with the proper tertiary strata: as I observed before. Properly, they rank here, in a just Theory. Yet let me remark, that such events ought to have occurred in every anterior condition of the globe, as it certainly did at the formation of coal: whence perhaps have arisen some appearances in the antient strata, still requiring explanation, and also, some further examination. I might have said, that geologists have too much forgotten, that every antient state of the Earth must have resembled the present, as to its surface and the changes to which this was subject; but they have not even imagined these former Conditions; with but a limited exception. What such considerations, and many more which have preceded, will hereafter effect for geological science, remains to be seen: it will never be known by me; but it is some satisfaction to find that there is abundant work for the future, as I have here endeavoured to conjecture what it is; guided by the only beacon that an imperfect science can afford. If Geology is sleeping, let it rouse itself: we are ever hearing a great deal that is not true, very much that leads to nothing, and far more

than enough, of what we knew before. If I have done no more, I have at least shown that there are wide fields still unexplored; it will be long yet, before limited food will furnish excuses for what it is now doing.

And now, let any one compare what the preceding System has told, with what it did not know, and could not tell. I should be ashamed of it, could I have done it better: but if its defects are now visible, as I have desired to make them so, it is also easy to see what every system, in every science, must be: being, what I originally said, a view of what is or appears to be known, right or wrong; and no more.

I need not separate the deposits of Travertino, under whatever mode, from these alluvial rocks. But let it be remembered, that I have proved the indifference and versatility of marine animals with respect to the quality of water; since this is an important fact in the Theory of the Earth, as that regards Life.

Rocks are, now, as they have ever been, decomposed and disintegrated by the action of the elements; and I may safely consider their produce as the first among terrestrial alluvia. Being moved through the slow action of the rains and gravity, they become partially transported, towards vallies, or into them. The depth of such local decomposition is often very great: and in defect of better causes, this is presumed to be a fundamental source of denudations. The transporting powers of ordinary rains alone, seem insufficient for all but the smaller subsequent effects: especially when the alluvia themselves are not in the vicinity: but such torrents of rain as are conceivable after the revolutions of the globe, together with rivers which have diminished or disappeared, from the degradation of mountains, may also have constituted such a power; as may, further, oceanic currents, produced by some of the recent

partial elevations. But I cannot allow that any such temporary current, however energetic, could demolish solid mountains. Thus does a full theory of denudation remain among the obscurities rather than the blanks of a perfect Theory of the Earth.

The action of rivers has, from the commencement, transported from the higher lands, the materials and fragments of rocks, produced partly in the manner just stated, and partly by their own force: thus generating another class of alluvia. And these fill the cavities of lakes and vallies, extend the maritime plains, excluding the sea, and are, further, deposited beneath the ocean, to be the germs of future solid strata.

The sea, receiving these, receives also the fragments which the action of the elements, aided by its own, takes from its boundaries: thus uniting with the operations of rivers to enlarge alluvial shores, in return for the solid ones which are demolished. And such alluvia, being originally maritime, may, and do, contain marine remains. But as the sea line retires, they necessarily come to be found inland, and, sometimes, far removed from the present ocean. Being inferior, of course, to the subsequent fluviatile ones, they often also retain their original levels; yet are occasionally elevated to considerable distances above that of the present ocean. In both cases, they have, negligently, been ranked with tertiary strata. In the latter, they are, strictly speaking, elevated marine alluvia: but while they ought to be distinguished from those, under this name, first enumerated, since they are not the consequence of great, if partial revolutions, so is it proved that the relative level of the sea and land vacillate, and that such elevations have been the result of this tedious and almost imperceptible action. And there is no evidence of any other cause of the apparent diminution, or increase, if

that has been said, of the ocean, or of any limited seas, than either this vacillation, or that filling up of basins and straits, through alluvial deposits, which affects the former, under obvious causes, and, the latter, under the consequences of tide currents. I will here add, that the alluvia of disintegration, of previous conditions of the earth, explain the local conglomerates; as the general ones find their explanation in those of a more general nature, terrestrial or marine, tumultuary or otherwise.

The last alluvial deposits consist in the agricultural soil, and in peat. The former is the produce of the gradual decomposition of rocks and fragments: it is transported, universally, by means of rain simply; partially, but more rapidly, by rivers; and it becomes mixed with decomposed vegetable matter. The latter consists of this vegetable matter alone, which I have shown to be a hydrocarbonaceous compound, produced by the action of water, and resembling that which is formed by a close or modified heat; not being bituminous, but finally becoming so, and thus producing lignite, first, as it is also the preparation for future coal. And it is formed under the sea and on its margins, under lakes and on their shores, in marshes, and on ill-drained places or declivities; as it is, further, the produce of fallen forests, and is also occasionally transported, in a powdery state, by the flow of water. Occupying distinct deposits, or strata, it may also alternate with alluvial earthy ones, and further, with shells, or marl; thus representing the successions in a coal field. I have only to add, respecting two very partial alluvia, that I can discover nothing in those of the Caves and the Fissures, justifying the hypotheses on those subjects, or requiring any but the most obvious explanations.

I have done: and I leave this sketch to its fate: as I leave its evidences to the judgments which are able and willing to examine Evidence, and its blanks to the industry and talents of future geologists. I have said, that I would gladly have given it in a far other form: with all the illustrative evidence and expansion which it requires, and with those drawings, without which, it is but a truth, that I cannot, myself, read it satisfactorily, after it is thus written. But writers must conform to what they cannot command. The spirit of commerce has discovered the art of obstructing what does not fill its own coffers: and, unfortunately, in the algebra of life, the multiplication of two negatives is not a source of production. It is, however, but a chain of fragments: nor must it be tried on the plea that it is a Theory of the Earth. I do not believe that a complete one will ever be produced; because I think there is much that is inaccessible. And even a more perfect one must be of slow growth, because it must depend on tedious accumulations of knowledge. But there is not a philosopher, versed in this subject, and capable of comparing what has preceded with that which was examined in the foregoing chapter, even where most rational, who will now say that a Geological Theory, to some tolerable extent at least, is a subject of despair, far less that such a term should excite ridicule; while, of those who are in ignorance, or who judge from such attempts as Werner's and many more, philosophy takes no heed. And I do not hesitate to say, that the progress thus made, in the far most difficult branch of Natural History, in so short a period, under very little effective, through much ostensible assistance, and under the most enduring obstructions, through false hypotheses and bad observations, is such as to have no parallel as yet in the history of Science.

Need I now add, that independently of its practical value, Geology occupies a lofty place among those sciences which tend to enlarge our views of the plan and conduct of the Universe, and of the government of its Great Author. It teaches us that this Earth had a beginning: it almost introduces us to the very act of Creation: while, by rigid inference or by analogy, it also teaches us this of the Planetary system, and, finally, of the whole Universe. Theology and metaphysics might have inferred this, as they have often done: but no other branch of physical science has ever dreamt of attempting to prove it: while I know not that any science, excepting that of abstract quantity and number, has ever produced proofs so satisfactory, on any point equally wide and out of reach. Doing this, important as it is for the satisfaction of minds which, from various causes, the *priori* conclusions of Theology and metaphysics do not reach, geology also confirms that Record which informs us that Life was created at no very remote period, by demonstrating that there was a time without previous life, and that this also is a repetition of the conduct of the Deity at many preceding ones.

It shows us further, that, as to the Earth itself, the plans of Providence are progressive and slow; as they are, in all else which we witness of His government: slow, to us, to whom Time is a weighty element, but not to Him, to whom a thousand years are but as one day. Thus ought they who have so long hesitated or feared respecting the Time demanded by geology, to fear or hesitate no longer. The past of Man, like the future, is the Creator's present: but foolish man would measure that Being by himself. I will not repeat what I formerly said of the time required for the successive modifications of this globe; but he who

has read what has now been written, will see how much further he may venture, even till he loses himself in a series of ages, which, to our narrow conceptions, is almost an eternity. And have I not shown that what is thus consistent with the Conduct of the Deity is also not inconsistent with His revealed Word? If I have not, I have proved nothing; if there were aught in geology which contradicted that Word, I should be among the first to say, the science is in error.

But it is not in error: it is one of the strongest evidences, towards natural religion, as it is also a new one. For thus too do we discover the wisdom and the goodness, which, never leaving the earth without that Life which it was capable of supporting, has ever adapted its forms to those capacities: just as, during our own period, it changes the balances of the present ones, as the habitation itself changes, under His direct power, or under the subsidiary and appointed powers of Man. And does it not also teach us, that His Will interposes when needful; that not even a secondary cause can, always, act, under that previous appointment which an antient philosophy had supposed, and a modern one has, unwarily or censurably, followed? Can the periods of revolution have occurred without His immediate interposition and command? And this is His Providence. Worthy surely therefore of regard is a science which thus demonstrates the chief attributes of the Deity, and thus elevates our minds to the Creator and Governor of all: which teaches us further, that all progression is improvement; almost also assuring us, that the destruction in which we have been taught to believe, shall be succeeded by a better and a fairer earth, when He shall think fit to issue the Command.

THE END.

APPENDIX.

I. *On the Instruments requisite to a Geologist.*

THE construction of geological maps cannot be too strongly recommended, though they should never see the light; since thus only is practical accuracy attained. While such a map also saves pages of unintelligible description, there is much information that can be conveyed in no other manner; as no confidence can be placed in mere description, where more than one rock is concerned. Thus also does it become a test of the observer's fidelity; while, if that which has been accurately examined is easily detailed, so must we distrust written reports of matters demanding much attention and labour, if that which is comparatively easy has been neglected.

But as such a map is sometimes the geologist's object, he must commence by the careful choice of a topographic one; since, if defective or erroneous, it becomes the source of much labour and much doubting. They alone who know the facility afforded by a good map, and the vexations of a bad one, will appreciate the importance of this object. It cannot well be too large; from the narrow extent of many rocks in nature; while it may often be necessary to enlarge certain portions for this purpose. A multiplicity of details is also indispensable. Roads, rivers, hills, houses, and villages, form the *reticulum* for the geologist's observations; while, according to the number and accuracy of these, will be the facility and the

value of his records: though, in desert tracts, his knowledge of surveying may sometimes be required. Thence also the most recent map should be selected; since the works of man, at least, are subject to changes, especially in improving countries; often causing egregious confusion, as at present in Scotland.

Excepting military maps, few contain the forms of ground, so important to a geologist. The want of objects in mountainous countries is but imperfectly supplied by rivers; and, without that, an accurate geological record will always be difficult. The nature, positions, and boundaries of rocks, are often indeed so intimately connected with these forms, that a military survey becomes invaluable; while they who have experienced its utility, will often gladly undertake this previous labour. It is to be wished that map-makers may at length become sensible of their neglect on this point; and that their conjectural symbols may be replaced by delineations to render their works of use to more than the mere traveller. To the geologist, the blackness of maps is also a serious grievance; as it deprives him of the use of broken and delicate tints, in distinguishing among numerous rocks. Nor is it required; since any ground can be fully expressed without it, as is proved by the recent maps of France and Italy: while, if often arising from misplaced ambition in the engraver, it is more frequently the fault of superintendents, ignorant of art. And a similar evil arises from loading them with symbols of forests and wastes, obscuring the much more important forms of the ground.

All boundaries of rocks should be laid down, in the field, in the selected colours: and unless this be done, the produce will deserve no confidence: while the observer himself will soon find that he can ensure accu-

racy in no other way. He who produces a map from his journal, cheats himself as well as his readers: of maps compiled from the notes of others, I can only say that they might as well not have existed, if there be any meaning in the term map, or any purpose in geological topography: while I should insult the most ignorant reader, by a remark on the attempt to produce such a map from collected specimens.

For verifying positions, a portable compass is generally sufficient: and it should be elevated on a staff, partly for convenience, and partly to avoid the effect of local magnetic influences, far more common than is suspected, especially in districts of trap. For more minute observations, the two-inch sextant is peculiarly convenient, where all must be portable; while the necessity for a spirit-level cannot often occur. If complicated and bulky machines have been invented for taking the elevations of strata, their weight is not the only objection; since these cannot be discovered from single, or even from many partial observations. Few strata present surfaces sufficiently level, or so coincident with the general plane, as to permit of a true measurement through the base of these quadrants; as many rocks also are inaccessible. But as the profile can generally be seen, a small ivory quadrant of two or three inches radius, or, for a less accurate eye, a similar one which I have constructed from mica, will serve to determine the angle, by prolongation or coincidence; and with an accuracy as great as from partial observations through other instruments, whence, after all, an average must be deduced. Nor can a tolerable eye require an appended plummet to determine the perpendicular; though this also is easily applied. And this simple instrument is equally applicable to a tangible stratum, by means of a straight

staff; with results even more true than those of the instruments to which I have objected: though every geologist ought to know, that nothing is gained by this fantastical accuracy. Where rocks are inaccessible, a pocket telescope will often be of use; but let no one imagine that he can thus supersede the necessity of a manual examination.

If it has been the fashion to record the altitudes of hills, this is rather a question of physical geography. Yet they who have this ambition, must submit to the trouble of a barometer; careful, however, that they do not mislead themselves, in the use of that which requires many minute attentions; the most frequent of its errors arising from the gradual admission of air, as the fault is also not discoverable till correction is impossible. The pressure of the air itself is undergoing frequent, and, often, sudden and considerable alterations; so that imaginary differences of altitude are sometimes inferred, from this cause, acting during the intervals of observation, or, under the use of distant instruments, or, still more, under travelling observations referred to a remote barometer. By comparing the registers of Gordon castle, Kinfauns, Mr. Playfair, and Greenwich, all carefully kept, I long ago proved, in a paper which the Geol. Soc. did not print, that under a varying state of the atmosphere, the changes are very far from simultaneous in different places.

It is barely sufficient to name such things as a measuring tape and a chisel; while, for blasting, the geologist must trust to occasional assistance. But in spite of inexperience or indolence, let him be assured that he can decide on no rock on which he has not laid his hammer. Their physiognomies are uncertain, they are often obscured by decomposition or by lichens,

and the superficial characters are often also different from the real ones; from their containing water, as I formerly showed. This fact, hitherto unobserved, cannot be known, unless from deep-seated specimens; and hence the necessity of more powerful hammers than those in use. The form therefore becomes an important object; that we may command the greatest force with the least encumbrance.

The hammer of quarrymen is a double truncated wedge: while nothing but extreme ignorance of mathematical principles could have extended this form to those of road-makers and geologists: whence their inefficiency, even under an inconvenient increase of weight. The fragment, in each case, is produced by exciting a vibration in an imaginary lamina, through a motion too sudden to be accompanied by that of the adjoining parts. It is forgotten that the communication of motion is not regulated by the momentum, simply, of the moving body. The weight and the velocity cannot be indifferently interchanged: and thence strange errors in many other matters also, of daily practice. But, not to enter further on this subject, suffice it, that it requires a time inversely proportioned to the tenacity of a body, to allow it to be displaced in a mass; whence, if additional momentum be required, the weight, not the velocity, must be increased. But if it is required to disintegrate the same body, it is the velocity that must be augmented. It is by impulse that the stone is broken in the present case. Hence it is useless to increase the weight of such a hammer, beyond that to which the hand can give the greatest velocity, since there is thus a loss of power. I have taken four pounds as the extreme weight; while two, or less, will, in a proper form, suffice for most rocks.

But that form depending on the mode in which rocks split, the whole impulse should fall on as narrow a line as possible. In practice, however, that cannot be; because the centre of percussion of a wedge cannot easily be made to impinge vertically on a surface. But the same object is sufficiently attained by the impulse on a point, through a spheroidal form: as, in a sphere, it is evident that every direction will be, equally, and always, fully, effectual. But this being difficult to construct, is also unnecessary, while the oblate spheroidal form is even better; since the curvature of the equatorial portion allows of a narrower point of contact, with an equal weight, than a sphere would do: the breadth of that contact diminishing the power, for obvious reasons. With such a hammer, while every blow is effectual, it may be used blindfold, when the wedge hammer fails oftener than it succeeds; while, admitting a round handle, and demanding no grasp, its head also forming no lever against the hand, as the long wedge does, it requires no muscular exertion in the fore-arm, and cannot strain the wrist by missing. Its duration too is almost eternal; since, if too hard, the steel cannot chip off, while, if too soft, any former indentation is filled by a second blow. If, thus saving labour, our labourers have not adopted it, after fifteen years, it is perhaps explained by the indignation of the Welsh quarryman at the presumption which could propose a better hammer at this age of the world. And the best form for trimming hammers, is that of a tripled cube of steel, the weights ranging from three drachms to an ounce; as the smaller fragments demand the least weights, according to the foregone remarks on impulse and momentum. While also such a hammer possesses eight cutting edges, by reversing the handle, it is quickly repaired by grinding the two

faces, when double the labour, in the chisel form, replaces but the original two.

II. *On the Construction of Geological Maps.*

If I point out a few rules for the construction of geological maps, experience will soon teach where they may be modified or improved. On a black map, it is impossible to render intelligible a numerous or intricate set of rocks, by any system of colouring; and hence a more vacant duplicate may become necessary. It has been proposed to associate certain colours with specific rocks, as their permanent emblems: but no project for this end has fulfilled the conditions, as it is in reality, impracticable. In such a hieroglyphic language, there ought to be a sufficient number to allow one for each rock, each ought to be readily distinguishable, however approximated, intermixed, or minute, and each should also be immediately referable to the key. They should further admit of being associated in groups, indicating those of the rocks themselves; while, to unite harmony of effect with this, would complete every thing. Something must therefore be surrendered: and, this is, all hope of a distinct tint for each rock under every circumstance of approximation and extent, so that every mass will require its own key; while this is fully compensated by the advantages retained, and the resulting clearness.

Though the distinct tints are numerous, not many can be distinguished on an engraved map, under their frequently minute spaces and intermixtures; while, to increase them by dots or hatchings, is only practicable on a pale map and a large space. But I need not give a catalogue: remarking only, that it is convenient to reserve the intense and the opaque colours for the smaller spaces. Experience must still be the

guide: yet while nothing must be sacrificed to precision, a cultivated taste will contrive to produce a pleasing effect through the harmony of colouring. But the utility of such a map is much increased by thus pointing out the affinities of rocks; so that a glance will teach more than long descriptions: while it is the reproach of geologists to have hitherto neglected this. On this subject, however, a few hints must suffice, where details would be tedious. Thus, in a secondary series, might the beds of limestone and of sandstone be associated by congenerous tints, thus might primary be distinguished from secondary strata, and thus might the unstratified rocks be associated, and also contrasted with the strata; with much more that I need not now point out.

If the dips of strata have been indicated by strengthening the tint on the elevated edge, this produces confusion: and though a dart with a number are preferable, we cannot convey a true idea of dips and superpositions, without sections; the data for which can sometimes be procured, but must often be inferred; while imaginary must therefore be substituted for true ones, taking care to avoid hypothesis. And by colouring these conformably to the map, with a symbol declaring the line of the section, the geologist will have done all in his power to render his labours useful.

III. *On conducting and describing Geological Observations.*

Though the surface is extensively covered with loose materials, the rocks are sometimes exposed, as they can often be discovered through artificial works. And that which cannot be seen, is inferred through the powers of geological analysis; whence we learn to ana-

tomize the rocks beneath the surface, by the penetrating eye of science. In hilly countries, investigation is comparatively easy; as the cliffs of mountains and of sea coasts often display, not only the rocks themselves, but their order of succession and their minuter circumstances; teaching us also to construct sections, or serving to check those which we have inferred from more difficult comparisons of the surface. He who can commence from such a point, has often gained a firm foundation for his work; since he can thus extend the same conclusions to places of greater obscurity.

Mountains which exhibit no precipices demand more attention: yet, by giving passage to streams, they often display enough of their structures; though patient investigation is here especially required, since true deductions can only be made by the comparison of many observations on the nature and positions of the rocks; while the geologist must add all his preliminary knowledge to industry and acuteness. And here also must he carefully record observations; since the truth is generally to be obtained but by a distant and final comparison. And though deficient in streams, protruding rocks often convey sufficient indications of the internal structure: although the student must be careful not to mistake transported for fixed ones; while, if the sound on being struck, and an irregularity of position in stratified ones, offer criterions, there are other circumstances which words can scarcely convey, but which experience will give; forming him to that tact so well illustrated in "Zadig." If superficial observers have too often trusted to the stones deposited by rivers, they teach little or nothing: while, being often derived from antient alluvia, they cannot even indicate their birth places; as, in no case, can they instruct us respecting the successions or positions of any rocks.

If the general covering of soil and cultivation, in low countries, forms a source of difficulty, the regularity of the strata often produces countervailing advantages. Under a low position, they commonly occupy such large spaces, that a few points will often determine an extensive tract; while, in mountainous regions, the frequent changes of the rocks demand much more labour. The first steps may indeed be slow; but when a few strata, with their successions, have been ascertained, the subsequent labour becomes light: while a final comparison will disclose what was at first concealed. If horizontal, or nearly so, it may often require time to ascertain the strata; while quarries, wells, and mines must be searched, for what rivers seldom disclose in these cases. But such positions are rare, while the unequal declivities, in inclined stratifications, indicate the elevated edges, which may be pursued by occasional fractures and by the form of the ground; as this last, with the nature of the soils, aid us in tracing the succession and place of each stratum. But if many other circumstances require attention, the following remarks on the description of geological appearances will comprise every thing needful.

The general character of the country, with its mountains, vallies, lakes, rivers, coasts, and any other circumstances of physical geography bearing on geology, first demand attention. And the alluvial deposits more conveniently follow, than in the order of superposition as strata, from their connection with the preceding subject; permitting thus a more luminous view of the whole. In these, the several kinds must be distinguished; together with their origin and causes, demonstrable, or probable, and the effects they may have produced as to the surface. It is by thus studying and describing those of foreign and obscure origin, with

those of disintegration and of partial transportation, that we shall obtain descriptions not hitherto given; while if, under the fluviatile alluvia, the several effects in changing the original surface especially demand attention, so, in describing the maritime ones, not only should the changes of the coasts be noted, but the soundings of the neighbouring seas and the alterations which the relative level of the sea and land appear to have undergone. In connection with this, should also be described the deposits of peat, with their associated marls, together with the organic fossils of the alluvial soils: while I may here say, once for all, that these will demand attention in every subsequent description of the strata, under all the circumstances of their nature, positions, &c. which may throw any light on a subject often obscure. In describing the rocks of a district, it is generally convenient to commence with the lowest, as, with granite, if present; thus ascending through the strata, and terminating with the trap rocks, or, if they exist, with tertiary deposits and volcanoes. Yet it is often convenient to proceed in the reverse order: while, if no absolute rule can be given, the object is to gain some fixed point of departure to which every thing can be referred, that the reader may acquire correct ideas, not of the names alone, and geographical places of rocks, but of all their relations. The endless volumes of useless description, compel me to caution the geologist against imagining that he has described a district by the mere enumeration of its rocks; often even careless whether they are not transported and foreign substances.

In granite, the extent and position of the masses should first be noticed; with any rational inferences respecting what is invisible. To this must be added its disposition, with its concretionary or other forms, as also

those circumstances of contact and of veins by which the relative ages of any masses may be inferred; with, of course, its connections and contacts with adjoining strata, and the several phenomena of its veins. And as the varieties of this rock are highly interesting, especially under its passages into trap, a correct description of its mineral characters is necessary. And I may add a remark applicable to all rocks, viz. that the geologist should ever bear in mind the various opinions on these subjects, whatever he may himself believe: since these will sharpen his attention, and direct him to much that might otherwise escape his notice.

The antient porphyries having been generally ranked with the stratified substances, we have been much misled by their descriptions; but the same rules may be adopted for these as for granite and the traps: taking care especially to note those circumstances by which their ages may be inferred, in reference to granite and to the associated strata. In the trap rocks, the same general rules apply, as far as all the circumstances of position, extent, general forms, structures, mineral characters, relations to the strata, junctions, and veins, are concerned. Here also it is requisite to distinguish between successive formations and their relative ages; while, as masses, now independent, have often been formerly connected, the geologist must bear in mind all these facts, as already described, and also recollect that the antient existence of even extensive tracts can often be inferred by only the most delicate evidence. Thus do their present connexions with the stratified rocks demand the most careful attention, and often much laborious comparison. On their mineral characters I should add, that they will often require acute discernment respecting the distinctions of mixed minerals, as may their intermixtures of character; yet the

student must never, in any thing, encumber his descriptions with superfluous circumstances; while, if it is the business of a discerning mind to select the useful, even from what is unknown, this quality of philosophical foresight cannot be communicated by any instructions. I must also call his attention to the conglomerates, hitherto so ill understood, to the connexions of organic substances, especially of coal or lignite, with them, to that frequently scoriform character which proves their volcanic origin, above all to a careful discrimination of the veins, lest he mistake them for strata, and lastly, to those real strata which appear to have been fused *in situ*. But the former history of these substances will amply teach him what I need not further enforce. Wherever, lastly, the country under review combines existing, or admittedly antient volcanoes, with rocks of this class, unusual attention will be required on a subject not yet sufficiently elucidated; while respecting volcanoes themselves, and their products, I can only suggest the necessity of scientific examination; since, of the wonderful, we have already more than enough.

Respecting the stratified rocks, it must first be remembered that the order of succession is inconstant; so that they should be examined without any previous hypothesis, and described as they exist. There is nothing in the whole circle of geology in which this rule is more rigidly to be enforced; since, in nothing, are we now more deceived by fanciful and false statements. And let every reader distrust or neglect him, who, instead of duly searching, and simply and fully describing, adopts the system and phraseology in vogue. As to the details, the first relate to the place and extent of a given stratum, and to the inferences respecting its probable continuity, when no longer to be fairly traced.

Its thickness, changes of dimension, inclination, curvatures, fractures, and other obvious matters, follow; while I have already said, that such inclination can never be determined from partial observations. Nor let fissures and joints be confounded with the divisions of strata, nor the concretionary laminar structure with the effects of stratification. It is by such attentions that the correspondence or continuity of distant strata are traced; as thus also we learn to supply that which cannot be seen.

As to successions of strata, much more is required; implying the order of those, the nature of the rocks, in all their mineral characters, the modes of division, and, above all, the parallel groupings, and the separations of such groups from others in reverse order, together with the peculiarities of structure in such places. Thus it is that we discover the points of revolution, and also learn to trace all the partial deposits. As to inferior groups, let the geologist ever remember how much of hypothesis there is, and hence be cautious lest this mislead him from the truth, which, if he truly seeks it, he will find. The accidents which depend on the unstratified rocks must be already understood: and as to any peculiar circumstances engaged in the successions of strata, it is sufficient to refer to the preceding chapters. Yet under the investigation of great tracts, let the geologist also attempt to define the limits of sets of strata, and to determine the circumstances under which they were deposited; and further, how far there are correspondences under obvious differences, for in this too have we been egregiously misled. And lastly, let him ever recollect that he has neither formed nor conveyed a clear idea of his work, unless his reader can comprehend it as if given in a section, or can construct one from his de-

scriptions; while, without this, he will deserve that his knowledge be called in question.

Of the tertiary strata, I have already fully stated what I consider a true arrangement; referring also to the last chapter, in preference to the one which treats on that subject. To that the reader may turn for what I need not repeat; but let the substances be at least described as they exist; since, to give such names, alone, as "The plastic clay," or "the calcaire grossier" is to do worse than nothing. Let their elevations also and their relations to the inferior rocks be noted: as, through their physical geography, carefully examined, we shall distinguish them from those deposits with which they have been confounded. As to mineral veins, it is at least necessary that they should be carefully examined, and described in all their accidents; in the rocks which they traverse, in their contents, and in the variations of those: while further, under whatever circumstances pure minerals may occur, it is the geologist's duty to describe these, since it is to him that mineralogy must always be indebted for this knowledge.

Studying brevity as I have here done, it will still remain for the discretion and knowledge of an observer to add what he thinks may contribute to geological science; as he is permitted whatever may enhance its interest to the reader. But let him ever remember that if by commencing his career in England or Saxony, or by trusting to books and professors, he has determined that any given country is his pattern of nature and point of reference, he has already bandaged his eyes; for it is certain, that wherever he goes he will see nothing but the succession or "formation" in vogue; "the muschelcalk" or "the greensand," the The of his school or system. Let him study nature with his own eyes, and infer by his own reason: else will his Obser-

vation be but Opinion, and the opinions of thousands will be but the opinion of one.

IV. *On the Qualifications required by a Geologist.*

It has been the reproach of geology that it has been a history of errors, corrections, and controversies, a record of conflicting facts, contradictory authorities, and hypotheses. But this is the reproach of the cultivators, not of the science. Amid her variety as in her constancy, Nature is subject to laws; and they will ultimately be established by him, who, to the faculty of observing accurately, joins that of reasoning justly. And when observers shall come to their tasks with the previous necessary knowledge, when they shall bring to these, candid as well as inquisitive minds, when they shall study to distinguish analogies and differences, to discriminate between the accidental and essential, and learn to generalize this observation by the rules of sound philosophy, the truth will not long remain concealed.

So mutually dependent and connected are indeed all the sciences, that there is scarcely one which can be effectually pursued without previous acquisitions of various knowledge; as never was there a valuable treatise written on any subject, by him who did not know much more than what he has seemed to profess. Nor, in any one science, was ever yet any thing well done by any but a mind schooled in the habits of general observation and in the logic of philosophy at large. But these are well-known truths: it is here my object to point out to the geological student, those attainments in science and art without which he will learn nothing, and be unable to teach any thing. If the list shall appear formidable, there is nothing denied to industry, nor any thing demanded beyond what is essential to every scientific education.

A knowledge of mineralogy forms the very foundation of this science, often as that is forgotten; since, without it, the geologist will never acquire a ready and accurate knowledge of rocks, independently of the other demands on him which it possesses. There are also numerous appearances in geology, which I need not now enumerate, on which he will never reason justly without this knowledge; as the facts will even escape the notice of him who is, thus far, without eyes: while it might be invidious to notice the gross errors to which mineralogical ignorance has often given rise. Geology and mineralogy are indeed but two branches of a common science; while if discoveries in the latter must originate with the geologist, it is certain that these will be proportioned to his previous knowledge. If, with the botanist, not versed in the principles that distinguish their respective objects, the treasures of nature will pass before each, unnoticed and unknown. Nor can we place much confidence in him who pretends to distinguish among complicated and difficult appearances, when he has proved his deficiency in a subject of far easier attainment.

It is almost superflous, after this, to say, that a minute and ready knowledge of rocks is indipensable. It would be endless to repeat the cases in which it is in perpetual requisition, and the errors which have arisen from the want of it; though I may allude to the confusion of former geologists respecting pitchstone and jaspers, hornblende schist and trap, granite and quartz rock, with the pernicious conclusions and permanent ignorance to which these have given rise. Nor have we a right to suppose that all the rocks in nature are known. Quartz rock, hypersthene rock, augit rock, compact felspar, chert, and more, have been added, by my own researches, to a list not long ago deemed com-

plete; as have many other matters, often of great moment, been rectified or determined by these means alone. And, of all this, whatever yet remains, is reserved for him whose eye of knowledge is quickened to the apprehension of distinctions which escape an unprepared and careless observer.

It is a sufficient reason for the study of zoology and botany, that the organic remains of former worlds constitute one of the most interesting branches of their history. The subject is however so extensive, that it is too much to demand from the geologist an intimate acquaintance with it; though, without some attainments, in at least certain departments, he will often be obliged to resort to those who have bestowed undivided attention on these branches of natural history. Yet if this is an inconvenience, it is perhaps best as it is; since it is compensated by the greater accuracy arising from the division of labour. Yet let me still caution students against believing that the collection and arrangement of fossil remains constitute geology, or that a theory of the earth can be constructed from materials, which, though evidential of some parts of its history, are, with the sole exception of limestone, but incidental to its nature and progress as a planetary globe.

So entirely is geology dependant on chemical principles, that scarcely a step can be made in geological reasoning without their aid. All the theories of the earth are questions of chemistry; and had that science been understood by their propounders, geology would have escaped the censure due to those who have thus obtruded their ignorant speculations to enthral the minds of the equally ignorant. Without chemistry, the origin, nature, and effects of the igneous rocks, in particular, would never have been understood; as the labours of chemists have already materially elucidated

this subject: still destined, undoubtedly, to do much more, when the nature of the earths becomes better known, and when geologists shall be convinced, that without such knowledge, the teacher can as little deserve as he can claim attention. If there is any species of ignorance by which geology has hitherto been peculiarly obstructed, it has been by ignorance of chemistry. But it is neither needful nor possible to be a Berzelius; as it is not also a mere familiarity with details that will render the geologist what he ought to be in this science, but the command of general principles, with a readiness and power in applying them to new facts, and in disentangling complicated appearances.

Scarcely less folly has arisen from the want of mathematical knowledge among geological theorists; though I need make no remarks on that which is admitted to be indispensible to a scientific education. But omitting higher considerations, the geologist ought at least to be versed in plane trigonometry, and even to possess practical facility in all the ordinary operations of measuring; since they may often become necessary to the accuracy and verification of his work, as geographical errors may often materially impede his own deductions. Here let me also note the necessity of cultivating a geographical eye; that tact which, in different ways, distinguishes the military commander and the American savage; almost seeming in the latter, the result of some mysterious sense, as in the migratory birds. It is through this talent that the possessor immediately feels his situation in the most intricate country; recognizing even mountains and other objects, in positions before unseen, tracing their dependencies, estimating their distances, and even approximating to their elevations. Thus indeed only

can he apply his map to use; pointing out its several objects, in nature, and being thus enabled to record his observations, without error or hesitation. Thus also does he learn to see the mutual relations of distant strata, and to form the general plan of investigations to be afterwards verified by insulated observations. Nor can the possessor of this faculty long lose his way, even in the intricacies of a mountainous country; since, to him, the place of the sun is always known, while in every stream and every inclination of a stratum, he finds a pilot. The geologist who cannot be his own guide through unknown mountains, may be assured that he is but ill fitted for the work he has chosen.

The last qualification required is the art of drawing; the almost universal neglect of which forms one of the most singular defects in a modern scientific education. If it is difficult to proceed without it, in any of the practical sciences, it is indispensable in every branch of Natural history. There are a thousand objects which, from their bulk, or minuteness, or other causes, cannot be preserved; while, of many, verbal descriptions, however careful, are useless or inefficient: yet we have to regret that naturalists and travellers, in neglecting this simple acquirement, have rendered their labours nearly fruitless. It holds at least the next rank to the art of writing and reading; which might indeed be often well exchanged for it in these cases. If it is by letters that mind communicates with mind, it is by drawing, alone, that tangible and visible forms can be conveyed to the apprehension. It is the language of physical, as the former is of metaphysical knowledge. Thus also is it a valuable means of mental discipline; a great moral engine for the cultivation of the faculties. Whatever the inexperi-

London:
Printed by J. Teuten, 14, Dean Street, Soho.